

MERRIMACK RIVER BASIN  
DUNSTABLE, MASSACHUSETTS

MASSAPOAG POND DAM  
MA 00136

PHASE I INSPECTION REPORT  
NATIONAL DAM INSPECTION PROGRAM

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DEPARTMENT OF THE ARMY  
NEW ENGLAND DIVISION, CORPS OF ENGINEERS  
WALTHAM, MASS. 02154

NOVEMBER 1978

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Identification No.: MA 00136  
Name of Dam: MASSAPOAG POND  
Town: DUNSTABLE  
County and State: MIDDLESEX COUNTY, MA  
Stream: SALMON BROOK  
Date of Inspection: 22 & 30 August 1978

BRIEF ASSESSMENT

Massapoag Pond Dam is approximately 200 feet long and 12 feet high. The dam consists of earth embankments on each side of a timber weir. Side-walls of the weir are constructed of concrete. One 2 ft. x 3 ft. timber gate is present in the timber weir and serves as a reservoir drain. The age of the dam is unknown but records of repair work in 1949 and 1973 have been located.

The dam is in good to fair condition. There are no obvious signs of failure. It is therefore recommended that remedial work should be performed within two years of the owners receipt of this report.

Based on the size and hazard classification in accordance with the Corps of Engineers Guidelines, the recommended spillway test flood is the 100-year flood. Hydraulic analysis indicates that the spillway can only pass 36 percent of the test flood before overtopping the earth embankments. A 100-year test flood outflow would overtop the earth embankments by approximately 1 foot. It is recommended that an investigation be made on the earth embankments for the purpose of increasing the height of the embankments and allow the test flood to be confined to the spillway.

It is recommended that the hazard classification for this dam be changed from high to significant. This recommendation is based on our evaluation of the downstream conditions.

Additional investigations recommended include a detailed investigation to determine the condition of timbers now obscured by flowing water and overall stability of the timber weir as well as the before mentioned investigation to determine a method of increasing the embankment height.

Recommendations for remedial work include the clearing of brush and trees from the embankment, the providing of erosion protection on the upstream face of the dam, the repair of eroded downstream embankment surfaces, the

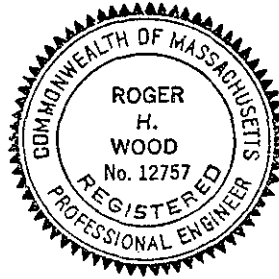


repair of local deterioration in the concrete sidewalls, and the repair or replacement of exposed timbers in the operating platform and foot bridge as well as repainting exposed timbers.

CAMP DRESSER AND MCKEE INC.

*Roger H. Wood*

Roger H. Wood  
Vice-President



This Phase I Inspection Report on Massapoag Pond Dam has been reviewed by the undersigned Review Board members. In our opinion, the reported findings, conclusions, and recommendations are consistent with the Recommended Guidelines for Safety Inspection of Dams, and with good engineering judgment and practice, and is hereby submitted for approval.

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CHARLES G. TIERSCH, Chairman  
Chief, Foundation and Materials Branch  
Engineering Division

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FRED J. RAVENS, Jr., Member  
Chief, Design Branch  
Engineering Division

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SAUL COOPER, Member  
Chief, Water Control Branch  
Engineering Division

APPROVAL RECOMMENDED:

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JOE B. FRYAR  
Chief, Engineering Division

## PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I Investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I Investigations are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the test flood is based on the estimated "probable maximum flood" for the region (greatest reasonably possible storm runoff), or a fraction thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. The test flood provides a measure of relative spillway capacity and serves as an aide in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

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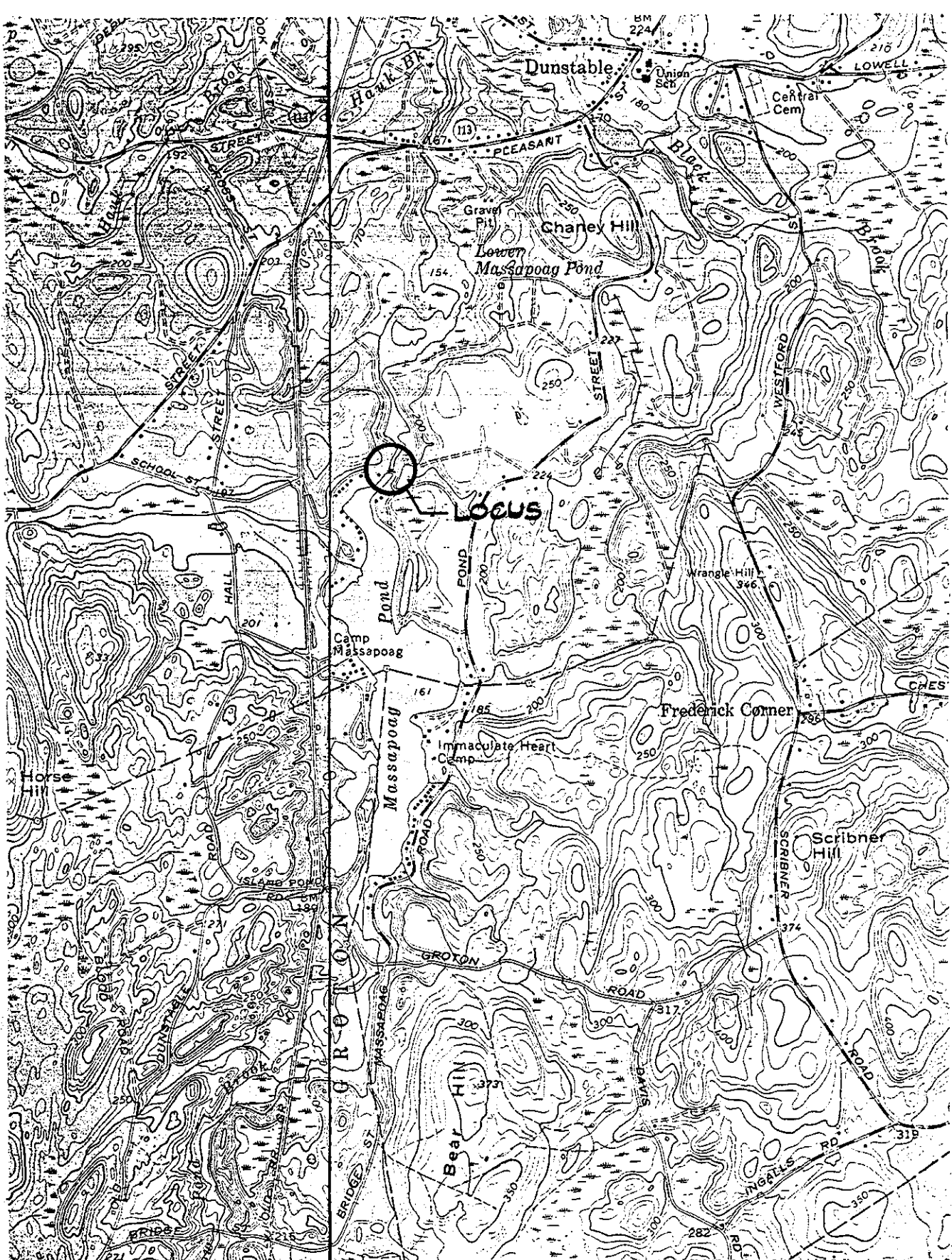
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1. OVERVIEW OF DAM FROM LEFT DOWNSTREAM EMBANKMENT. NOTE EROSION CAUSED BY FOOT TRAFFIC AT DAM LEFT ABUTMENT.





DAM: MASSAPOAG POND

IDENTIFICATION NO.: MA.00136



LOCATION MAP  
USGS QUADRANGLE  
NASHUA-SOUTH & PEPPERELL, MA  
SCALE 1" = 2000'

PHASE I INSPECTION REPORT  
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MASSAPOAG POND DAM  
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SECTION 1: PROJECT INFORMATION

1.1 General

- a. Authority - Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a national program of dam inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region.

Camp Dresser & McKee Inc. has been retained by the New England Division to inspect and report on selected dams in the State of Massachusetts. Authorization and notice to proceed was issued to Camp Dresser & McKee Inc. under a letter of 12 July 1978, from Colonel John P. Chandler, Corps of Engineers. Contract No. DACW 33-78-C-0354 has been assigned by the Corps of Engineers for this work. Haley and Aldrich, Inc. has been retained by Camp Dresser & McKee Inc. for the soils and geological portions of the work.

- b. Purpose - The primary purpose of the investigation is to:
- (1) Perform technical inspection and evaluation of non-Federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-Federal interests.
  - (2) Encourage and assist the States to initiate quickly effective dam safety programs for non-Federal dams.
  - (3) Update, verify and complete the National Inventory of Dams.

1.2 Description of Project

- a. Location - Massapoag Pond Dam is located on Salmon Brook in the Town of Dunstable, Massachusetts, as shown on the report's Location Map. The dam and spillway are located on the northern most portion of Massapoag Pond, approximately 1,500 feet upstream of Lower Massapoag Pond.



- b. Description of Dam and Appurtenances - Massapoag Pond Dam consists of an earth embankment with a concrete, steel and timber spillway structure located close to the left abutment. A timber gate and a walkway are incorporated into the spillway structure. The total length of the dam is nearly 200 ft.

The right dam embankment provides approximately 140 ft. of the total dam length. It is typically about 6 ft. high, but slightly exceeds 12 ft. alongside the spillway. Upstream and downstream slopes are somewhat irregular and flatter than 2 horizontal to 1 vertical, except close to the spillway where the downstream slope steepens considerably.

To the left of the spillway structure the dam embankment consists only of a short section of earth fill against the natural slope. It has a maximum height comparable to the right embankment but extends upstream along the spillway training wall to a considerably greater width.

- c. Size Classification - The hydraulic height of the structure is approximately 14 feet and the estimated storage capacity at the top of dam is 730 acre-feet. According to guidelines established by the Corps of Engineers, the dam is classified in the small category.
- d. Hazard Classification - The dam was originally classified by the Corps of Engineers as having a "high" hazard potential. The dam failure analysis indicates that sufficient flood plain storage exists downstream of the dam site to attenuate the failure outflow before it reaches the City of Nashua, without flooding any structures. If the culverts at Pleasant Street, Main Street, Ridge Road, and Searles Road were washed out, minor flooding could result to a few residences. Since the expected damages would be confined to roads, bridges, utilities, and agricultural lands, it is recommended that the hazard classification be reduced to significant.
- e. Ownership - At the time of inspection, the dam was jointly owned by the Cambridge YMCA (58 percent), represented by Peter Smargon, Director Cambridge YMCA, 820 Massachusetts Ave., Cambridge, MA 02139 (Phone: 617/876-3860) and the Pennichuck Water Works (42 percent), represented by John C. Collins, President, 11 High Street, Nashua, N.H. 03060 (Phone: 603/882-5191). At the time of this investigation arrangements were nearing completion for the transfer of the 42 percent portion of ownership from Pennichuck Water Works to the Cambridge YMCA. The Pennichuck Water Works obtained 42 percent ownership from Labombarde Interests in 1963. Labombarde Interests obtained ownership in 1948 from International Paper Box Machine Co.

- f. Operator - Mr. Howard Small of the Dunstable Rod and Gun Club is responsible for the operation of the dam. His address is: Hall Road, Dunstable, MA 01827 (Phone: 617/649-7273).
- g. Purpose of Dam - The dam was originally constructed to create a storage for release during periods of low flow for power generation by the International Paper Box Machine Co. Today, Massapoag Pond is used for recreational purposes.
- h. Design and Construction History - The dam is believed to have been constructed in the early 1900s. No records of the original design and construction are known to exist. The structure was repaired in 1949, the face of the weir replanked and a steel beam inserted for reinforcement. Additional repairs to the left wall and the gate were made in 1973.
- i. Normal Operational Procedure - There is no established routine for operation of the dam.

### 1.3 Pertinent Data

There are no known elevations previously established at the dam site. Consequently, the water surface elevation of 161 shown on the USGS Quadrangle, Nashua South, Mass.-N.H., 1965, was adopted as being the spillway crest elevation. All other elevations given in this report pertaining to the dam site were estimated from the assumed spillway crest elevation.

- a. Drainage Area - The drainage area tributary to the dam site is 13.56 square miles. The terrain surrounding the watershed is heavily forested with moderate side slopes. Drainage of the watershed is through a series of lakes, ponds, swamps, and brooks resulting in a rather flat watershed slope. The surface waters and swamps, including Massapoag Pond, account for about 53 percent of the total drainage area.
- b. Discharge at Dam Site - There are no records of discharges for Massapoag Pond Dam. The maximum recorded rainfall for the area was approximately 6" between September 17-21, 1938.
  - (1) Outlet works: 2-ft. wide by 3-ft. high gate at Invert Elev. \_\_\_\_\_ 151 (Est.)
  - (2) Maximum known flood at damsite \_\_\_\_\_ UNKNOWN
  - (3) Ungated spillway capacity at top of dam.  
372 cfs @ 163.65 elev.
  - (4) Ungated spillway capacity at test flood pool elevation  
625 cfs @ 164.74 elev.

- (6) Gated spillway capacity at test flood pool elevation\_\_\_\_\_N/A
- (7) Total spillway capacity at test flood pool elevation  
625 cfs @ 164.74 elev.
- (8) Total project discharge at test flood pool elevation  
1,020 cfs @ 164.74 elev.

c. Elevation (ft. above MSL)

- (1) Top of dam\_\_\_\_\_Varies from 163.65 to  
164.67
- (2) Test flood pool-design surcharge\_\_\_\_\_164.74
- (3) Design surcharge-original design\_\_\_\_\_UNKNOWN
- (4) Full flood control pool\_\_\_\_\_N/A
- (5) Recreation pool\_\_\_\_\_161.0
- (6) Spillway crest\_\_\_\_\_161.0
- (7) Upstream portal invert diversion tunnel\_\_\_\_\_N/A
- (8) Streambed at centerline of dam\_\_\_\_\_151.0
- (9) Maximum tailwater\_\_\_\_\_161.8

d. Reservoir

- (1) Length of test flood pool\_\_\_\_\_1.4 miles (Est.)
- (2) Length of recreation pool\_\_\_\_\_1.3 miles (Est.)
- (3) Length of flood control pool\_\_\_\_\_N/A

e. Storage (acre-feet)

- (1) Top of dam\_\_\_\_\_730 @ Elev. 163.65 (Est.)
- (2) Test flood pool\_\_\_\_\_880 (Est.)
- (3) Flood-control pool \_\_\_\_\_N/A
- (4) Recreation pool\_\_\_\_\_366 (Est.)
- (5) Spillway crest\_\_\_\_\_366 (Est.)

f. Reservoir Surface (acres)

- (1) Top of dam \_\_\_\_\_ 126 @ Elev. 163.65 (Est.)
- (2) Test flood pool \_\_\_\_\_ 133 (Est.)
- (3) Flood control pool \_\_\_\_\_ N/A
- (4) Recreation pool \_\_\_\_\_ 110 (Est.)
- (5) Spillway crest \_\_\_\_\_ 110 (Est.)

g. Dam

- (1) Type \_\_\_\_\_ Earth Embankment
- (2) Length \_\_\_\_\_ Approx. 140 ft., not incl.  
spillway
- (3) Height \_\_\_\_\_ Approx. 12 ft.
- (4) Top width \_\_\_\_\_ Approx. 12 ft.
- (5) Side slopes \_\_\_\_\_ Irregular, typically  
approx. 3:1 U/S & D/S
- (6) Zoning \_\_\_\_\_ Unknown, possibly earth  
fill over stone masonry
- (7) Impervious core \_\_\_\_\_ UNKNOWN
- (8) Cutoff \_\_\_\_\_ UNKNOWN
- (9) Grout curtain \_\_\_\_\_ Probably none

h. Diversion and Regulating Facilities -----None

i. Spillway

- (1) Type \_\_\_\_\_ Modified Buttress
- (2) Length of weir \_\_\_\_\_ 25 feet
- (3) Crest elevation \_\_\_\_\_ 161.0
- (4) Gates \_\_\_\_\_ None

- (5) U/S channel \_\_\_\_\_ 5 ft. rise in 10 ft.
- (6) D/S channel \_\_\_\_\_ 1,500-ft. to Lower Massapoag Pond
- (7) General \_\_\_\_\_ Good hydraulic condition

j. Regulating Outlets - The only regulating outlet at this structure is a 2 ft wide by 3 ft high timber gate with an invert elevation of 151 (estimated). The gate has a timber stem extending to a platform at the top of the dam. The operator for this gate was not present at the structure.

## SECTION 2: ENGINEERING DATA

### 2.1 Design, Construction and Operation Records

No records pertaining to the design, operation, or original construction of the Massapoag Pond Dam were located and none are believed to exist.

Construction records pertaining to repair work performed by C.M. Bacon and Sons, General Contractors, in 1949 and again in 1973 consist of the following:

1. Letter proposal from Mr. Clarence M. Bacon to Mr. Glenn C. Perduyn of the Cambridge YMCA dated March 5, 1949. Proposed work consisted of (A) - Rebuilding cofferdam at old location with a plank spillway 4' wide at center, using sandbag method and backfilling at least 3' with local material; (B) - Repairing hole at bottom of dam by holding water back and filling the hole with granite and clay, well placed and compacted; (C) - Reinforcing top member of spillway by placing a steel beam along the rear of present timber, said beam to be set into concrete walls at both sides at least 8", being well pointed up after setting, and then fit in 4 x 8 blocks to timber and lag in place; (D) - Removing present top walk timbers and placing one 10 x 12 hard pine second hand timber of sound quality to carry gate house timber bolted in place and reinforcing gate house; (E) - Covering the face of the dam (spillway) with new 2" spruce plank, well nailed with 30d spikes and place new plank on gate.

Some or all of the above proposed work was performed in 1949 but no records were found which detailed the completed repairs.

2. An invoice from C. M. Bacon and Sons to the Cambridge YMCA dated October 23, 1973 summarizes the following work: "Repair work on dam at Lake Massapoag, Dunstable, Mass. required the removal of all wood from the left hand wall on the upper side of the dam (spillway) and replacing the 6" x 6" post set into the concrete. We also removed the gate and installed a new gate with a new post."

A sketch attached to the above invoice shows a section through the spillway with the following notes:

"West wall - concrete poured behind original wall"  
"All old timber removed from concrete on lake side"

"New uprights set into concrete"  
"Wall double planked with plastic membrane  
between planks and tied onto dam face"

## 2.2 Evaluation

Since no engineering records are available, the evaluation of the dam must be based primarily on the results of the visual examination which is detailed in Section 3.

## SECTION 3: VISUAL INSPECTION

### 3.1 Findings

- a. General - The visual examination of the Massapoag Pond Dam was conducted on 22 August 1978. The visual examination of the embankment was conducted on 30 August 1978.

In general, the earth embankments, spillways and outlet facilities were observed to be in good to fair condition. The downstream face of the timber spillway was obscured by flowing water. One entrance in the vicinity of the gate was made beneath the falls to observe the conditions. Further entrances were not made due to the limited visibility and the presence of the falling water.

Visual inspection checklists for both site visits are included in Appendix A and selected photographs are given in Appendix C.

- b. Dam - The concrete portions of the dam (the sidewalls of the spillway) were found to have local spalls, some efflorescence, minor vertical cracking, and local deterioration as shown in Photo Nos. 2, 4 and 5. Steel bars are present in the exterior surface of the left upstream wall. Deteriorated timbers are present just downstream of the weir in the left concrete wall as shown in Photo No. 6. A void is present on the rear face of the right sidewall at the downstream end as shown in Photo No. 7.

The timber weir was observed to be in good to fair condition. A portion of the downstream face of the timber weir was observed by going beneath the falls. The area observed was that portion immediately adjacent to the timber gate. The timber was found to be waterlogged and some members were found to be easily penetrated to a 3/4 inch depth with a geologist pick. As indicated above, timber adjacent to the left sidewall is deteriorated. This timber does not currently serve as a support for the weir.

The earth embankment located to the right of the spillway is generally in fair condition. There is no visual evidence of settlement, lateral movement or significant seepage, but there has been local erosion and material loss on the embankment slopes.

The following specific items were noted:

- (1) The lower part of the relatively steep downstream slope behind the right spillway wall appears to have been previously repaired by patching with concrete and rock fragments. The dam crest width is also reduced above this location. As shown in Photo No. 7, there is a hole



in the slope that extends 36 in. back into the embankment. The hole is apparently the result of a loss of part of the patching material. There is no evidence that seepage flow has either contributed to or resulted from the hole.

- (2) At its lowest point the top of the embankment is nearly 2 ft. lower than the top of the right spillway wall, resulting in approximately a 2 ft. freeboard above spillway crest elevation.
  - (3) Extensive foot traffic on the slopes and the top of the right dam embankment and the left abutment area has resulted in local erosion, slope flattening and reduction of the dam crest width, as shown in Photo No. 1.
  - (4) The upstream slope of the dam lacks erosion protection and is partly exposed sand and gravel. Because of the pond geometry, wave action would be expected to be minimal, however.
  - (5) There is a moderately heavy growth of trees and brush on the downstream slope and there are clumps of brush and young trees on the upstream slope, as shown in Photo Nos. 1, 2 and 3.
- c. Appurtenant Structures - The operating platform for the reservoir drain is in fair to poor condition. The end of the support beams for the platform have deteriorated as shown in Photo No. 8. The decking has started to deteriorate on the upstream end. The vertical support posts have deteriorated at the normal water surface line. One of the posts appears to have a temporary support scarfed onto it. The downstream face of the gate appears to be waterlogged timbers. The operator for the gate is not present at the spillway. Inspection records indicate that this gate was repaired in 1973. It is believed to be operational and it is estimated that it is operated by a pry bar.

The footbridge over the weir is in fair condition. A few of the deck planks are missing and the ends of the timber stringers have started to deteriorate as shown in Photo Nos. 8 and 9. The foot bridge and the operator platform require replacement of individual members and painting.

- d. Reservoir Area - The area around Massapoag Pond is generally wooded and extensively developed. There are approximately 3 cottages below test flood pool elevation 164.74. Present shoreline development at or below elevation 180 consists of approximately 77 cottages, 2 camps, and 350 feet of streets and roads. Although the dam site is located in the town of Dunstable, portions of the pond are located in Dunstable, Tyngsborough, and Groton.

The side slopes to the pond are highly variable and generally wooded. There is no significant potential for landslides into the pond which could create waves that might overtop the dam. No conditions were noted which could result in a sudden increase in sediment load into the pond.

- e. Downstream Channel - Immediately downstream of the dam is Lower Massapoag Pond followed by Pleasant Street - Rt. 113. The road elevation at the Pleasant Street culvert is estimated to be 166.0. The culvert is an 84" diameter corrugated metal pipe approximately 60 feet long. In the event of a dam failure, Pleasant Street would act as a secondary dam without being overtopped. The flood plain surrounding Lower Massapoag Pond, which would be inundated should the Massapoag Pond Dam fail, is presently undeveloped.

### 3.2 Evaluation

Based on visual observations during the site examination, the general condition of the project is good to fair. The concrete portion of the dam is in good condition with local spalls, minor cracks and limited deterioration present. The exposed timber portion of the dam, including the operator platform and foot bridge, are in fair condition. These items are showing deterioration, especially at the juncture of timber and concrete and timber and water. The portion of the dam containing timber continuously exposed to water is in good to fair condition. The timbers in this area are generally waterlogged with members showing loss of strength in the outer 3/4 of an inch.

While the embankment at the Massapoag Pond Dam is performing satisfactorily at the present time, the limited freeboard and partially unprotected slopes appear to provide significant potential for dam failure under conditions of higher than normal water levels.

## SECTION 4: OPERATIONAL PROCEDURES

- 4.1 Procedures - In general, there is no established routine for the operation of the dam.
- 4.2 Maintenance of Dam - The dam receives little maintenance except for occasional repairs.
- 4.3 Maintenance of Operating Facilities - The operating facility, including the timber gate, has received minimal maintenance. There is no formal maintenance procedure for this operating facility.
- 4.4 Description of any Warning System in Effect - There is no established warning system or emergency preparedness plan in effect for this structure.
- 4.5 Evaluation - For a structure of this type and classification, a periodic observation and maintenance program should be established to examine the dam, control tree and brush growth, maintain slopes, and maintain the timber weir and operating gate. This structure should be observed during unusually high rainfalls.

## SECTION 5: HYDRAULIC/HYDROLOGIC

### 5.1 Evaluation of Features

- a. Design Data - No hydraulic/hydrologic design data is available concerning this dam. Hydrologic analysis performed by Metcalf & Eddy, Engineers in 1960 estimated the "maximum expected flood flow" to be 2,900 cfs based on the Kinnison-Colby Formula (Rare Floods). They further estimated that "If the spillway abutments and embankment crest were raised 2.5 ft., the head on the spillway of 6.5 ft together with the storage in the pond would take the flow of 2,900 cfs."

Based upon the Corps of Engineers Guidelines, the recommended test flood for the size (small) and hazard potential (significant) is within the range of 100-year to 1/2 PMF (Probable Maximum Flood). Since the hazard potential is considered to be at the bottom end of the significant range (no expected structural damage), the 100-year flood shall be adopted as the test flood.

- b. Experience Data - The test flood (100-year) was estimated by two regional frequency analysis methods. The first method, developed by C. G. Johnson and G. P. Tasker of the USGS Water Resources Division resulted in a peak inflow of 913 cfs. The second method developed by S. W. Wandle entitled USGS Water Resources Investigation 77-39 resulted in a peak inflow of 1,060 cfs. The results of these two independent methods compare reasonably well and the more conservative value of 1,060 cfs has been adopted as the test flood inflow.

Surcharge-storage routing thru Massapoag Pond was performed to estimate possible flow reductions. The attenuating effect of the pond was found to be minimal and the test flood outflow was estimated to be 1,020 cfs.

- c. Visual Observations - The hydraulic condition of the spillway, including the approach and discharge channels, were observed to be in good condition. It was noted during the inspection that the right spillway abutment is approximately 7 inches higher than the left abutment.

A 3 foot wide wooden foot bridge spans the spillway and is located 3'-7" above the spillway crest. Discharges at or above this stage would be affected by this structure. However, the dam would be overtopped before this stage is reached as the lowest point on the earth embankment to the right of the spillway was estimated to be approximately 1 foot lower than the bottom of the walkway.

- d. Overtopping Potential - The maximum capacity of the spillway with the pool elevation at the top of dam (Elev. 163.65) is 372 cfs

which is about 36 percent of the test flood. The amount of flow passing over the spillway at test flood pool elevation 164.74 is 625 cfs which is about 61 percent of the test flood. At the test flood discharge elevation of 164.74, the low point of the right embankment will be overtopped by approximately 1 foot.

- e. Evaluation - Dam failure analysis was performed to determine the magnitude of downstream hazards. A peak failure outflow of about 2,800 cfs was estimated based on a 40 percent breach width of the right embankment. The analysis indicates that the Pleasant Street road and culvert, which is located about 1 mile downstream of the dam site, would act as a secondary dam with top of road at about elevation 166.0. The flood plain between the dam site and Pleasant Street consists of swamp and marshlands surrounding Lower Massapoag Pond. There is no development which would be affected by this flooding. The outflow from this reach would be controlled by the 84-in. diameter corrugated metal culvert. The sudden release of flow from Massapoag Pond by a breach would cause a rapid increase in the level of lower Massapoag Pond until its level coincided with the declining level of Massapoag Pond, at which time the two bodies of water would act as a single unit. The maximum water level in the combined ponds (Elev. 160.8) would represent a drop in water level of Massapoag Pond of only 2.85 ft. and the 84in. culvert would have a maximum outflow rate of about 370 cfs which would decline steadily after the above described equilibrium condition had been achieved. Although the additional storage in the swampy area between Pleasant and Main Streets would very likely attenuate this flow even further, the Main Street culvert could convey the 370 cfs flow rate with a total head loss of 0.82 ft., thereby resulting in a freeboard of more than 1.5 ft. at the Main Street culvert. Some flooding of the agricultural and low lands in the half mile reach between Pleasant and Main Streets would occur, but no structures would be affected. Salmon Brook, which flows from Lower Massapoag Pond to the Merrimac River, has more than adequate capacity to attenuate the 370 cfs as there is ample flood plain storage with no structural development for the next 3 miles downstream of Main Street.

In conclusion, the Massapoag Dam spillway is inadequate to pass the test flood and in the event of a dam failure, damages to only roads, culverts and agricultural lands would occur.

## SECTION 6: STRUCTURAL STABILITY

### 6.1 Evaluation of Structural Stability

- a. Visual Observations - There was no visible evidence of dam instability during the site examinations on the 22nd and 30th of August 1978. There was no evidence of movement of structural items. There was no evidence of embankment erosion or piping at a location of very slight seepage below the left spillway wall, and no evidence of seepage flow at the hole behind the right spillway wall. Therefore, seepage is not considered to pose a hazard to the stability of the downstream slopes.
- b. Design and Construction Data - There were no design and construction data available. Letters pertaining to repairs made in 1949 and 1973 were located. The 1949 letter indicates the strengthening of the spillway by adding a steel beam. A review of the letters indicate that the strengthening of the spillway was probably required due to deterioration of the structure rather than being required by inherent structural instability. Except for the May 1960 inspection report references to indications of earth embankment construction over original dry stone masonry, there are neither design drawings nor construction data which would show the embankment cross section and the physical properties of the materials in the embankments. The lack of significant seepage does indicate that the dam has a core material less pervious than the granular soils that are exposed at the surface.

The Massapoag Pond Dam is relatively low, and, in the absence of significant seepage, the typical 12 ft. top width and flatter than 2 horizontal to 1 vertical upstream and downstream slopes would be expected to provide adequate stability for present pond levels under static loading conditions.

- c. Operating Records - There are no known operating records available for the dam.
- d. Post-Construction Changes - Post construction changes have been made to the spillway. Changes to the spillway walls and to the support of the timber weir are mentioned in C.M. Bacon and Sons letters of March 5, 1949 and October 23, 1973 included in Appendix B. These letters indicate that the walls were originally of timber and that they have been replaced with concrete walls. They also indicate that the timber weir has been reinforced by the addition of a steel beam beneath the timbers. Support posts beneath the timber weir have either been replaced or new supports have been added. There are no known post-construction changes to

the dam embankment, although as noted in Section 6.1b., there may have been an original dry stone masonry dam. Previous inspection reports have recommended raising the dam embankment, but this has apparently not been done.

- e. Seismic Stability - Massapoag Pond Dam is located in Seismic Zone No. 2 and in accordance with recommended Phase I guidelines does not warrant seismic analysis.

## SECTION 7: ASSESSMENT, RECOMMENDATIONS AND REMEDIAL MEASURES

### 7.1 Dam Assessment

- a. Condition - The visual examination of the Massapoag Pond Dam embankment did not reveal any evidence of potential failure, but it did disclose a potential for overtopping by high water. The spillway, due to the low elevation of the adjacent embankments, was determined inadequate to pass the test flood. This potential warrants near term remedial treatment. Because of this, and the condition of the spillway, the project is considered to be in only fair condition.

Maintenance should be performed and an additional investigation undertaken as outlined hereinafter.

- b. Adequacy of Information - Since there were no available drawings, all information for the Phase I Investigation has had to be obtained from visual examination and limited measurements at the site. This information has been sufficient for the purpose of this investigation, but it does not permit the further evaluation of stability of embankments and spillway and embankment seepage that would be necessary if the embankment is to be raised.
- c. Urgency - The recommended additional investigation and remedial measures outlined in Sections 7.2 and 7.3, respectively, should be undertaken by the Owner within the next two years after receipt of this report.
- d. Need for Additional Investigations - Additional investigation should be performed by the Owner as outlined in the following section.

### 7.2 Recommendations

It is recommended that the Owner engage a registered professional engineer to undertake the following investigations:

1. An investigation to arrive at modifications to the embankment cross section to raise the crest elevation. The investigation should include topographic survey to determine the configuration of the present embankment and test borings to determine the character of the embankment and the foundation and abutment soils.
2. An investigation during a period of no flow over the spillway weir to determine the detailed dimensions of the weir and the detailed condition of the individual timbers.



### 7.3 Remedial Measures

a. Operation and Maintenance Procedures - It is recommended that the following remedial work be undertaken by the Owner, in addition to the investigation outlined in section 7.2, to correct deficiencies noted during the visual examination:

1. Repair and restore the downstream embankment slope and the dam crest width behind the right spillway wall by improving erosion protection at the toe, removing loosened or undermined material and vegetation on the slope, and reconstructing the slope to adequate dimensions.
2. Clear brush and trees from the embankment, including stump removal and backfilling, establish a vegetative cover, and cut grass and weeds on the embankment at least once a year.
3. Provide erosion protection where it is lacking or deficient on the upstream face of the dam, and repair locations where the dam cross section has been reduced due to foot traffic or water action.
4. Replace the deteriorated members in the operating platform and footbridge.
5. Paint all exposed timber members to minimize future deterioration.
6. Remove all minor vegetation from concrete surfaces and remove all deteriorated concrete. Local spalled and eroded areas should be patched.
7. Remove the deteriorated timbers from the left sidewall just below the timber weir and replace the removed timbers with concrete.

Items 2. and 3. of the recommended remedial work will probably be combined with dam modifications to raise the crest elevation that would result from the additional investigation recommended in Section 7.2.

Due to the hazard potential and condition of this dam, surveillance of the dam should be provided by the Owner during and following periods of unusually high precipitation. The Owner should also develop a formal emergency procedures plan and warning system in cooperation with local officials in downstream communities. Finally, it is recommended that the owner establish a formal program of annual technical inspections.

APPENDIX A

INSPECTION TEAM ORGANIZATION AND CHECK LIST

Page No.

VISUAL INSPECTION PARTY ORGANIZATION

A-1

VISUAL INSPECTION CHECK LIST

Dam Embankment

A-2

Spillway

A-3

Outlet Works

A-5

Hydrologic-Hydraulic Considerations

A-6

Sketch of Dam

A-7

VISUAL INSPECTION PARTY ORGANIZATION  
NATIONAL DAM INSPECTION PROGRAM

DAM: Massapoag Pond

DATE: August 22, 1978

TIME: 5:15 p.m.

WEATHER: Clear - calm - 75° F

WATER SURFACE ELEVATION UPSTREAM: 1-1/4" above spillway crest.

STREAM FLOW:  $Q = (3.2)(24.67') \left(0.10'\right)^{\frac{3}{2}} = 2.50 \text{ cfs}$

INSPECTION PARTY:

- |   |       |
|---|-------|
| 1. <u>Roger H. Wood</u>                                 | } CDM |
| 2. <u>Joseph E. Downing</u>                             |       |
| 3. <u>Charles E. Fuller</u>                             |       |
| 4. <u>Peter LeCount - Haley &amp; Aldrich (8-30-78)</u> |       |
| 5. _____  |       |
| 6. _____  |       |

PRESENT DURING INSPECTION:

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_

VISUAL INSPECTION CHECK LIST  
NATIONAL DAM INSPECTION PROGRAM

DAM: Massapoag Pond

DATE: 8/30/78

EMBANKMENT: Dam

CHECK LIST	CONDITION
1. Upstream Slope <ul style="list-style-type: none"> <li>a. Vegetation</li> <li>b. Sloughing or Erosion</li> <li>c. Rock Slope Protection - Riprap Failures</li> <li>d. Animal Burrows</li> </ul>	1. a. Brush & young trees except where bare sand & gravel. b. Bare areas, apparently erosion from foot traffic c. None evident d. None observed
2. Crest <ul style="list-style-type: none"> <li>a. Vegetation</li> <li>b. Sloughing or Erosion</li> <li>c. Surface cracks</li> <li>d. Movement or Settlement</li> </ul>	2. a. Sparse grass in sand & gravel b. Slight erosion from foot traffic & at top of paths c. None evident d. No indication that irregularity is due to settlement.
3. Downstream Slope <ul style="list-style-type: none"> <li>a. Vegetation</li> <li>b. Sloughing or Erosion</li> <li>c. Surface cracks</li> <li>d. Animal Burrows</li> <li>e. Movement or Cracking near toe</li> <li>f. Unusual Embankment or Downstream Seepage</li> <li>g. Piping or Boils</li> <li>h. Foundation Drainage Features</li> <li>i. Toe Drains</li> </ul>	3. a. Trees (to 18" dia.), some brush except at paths. b. Erosion due to traffic on paths; patching w/concrete & rock behind end of rt. training wall; some of the rock has been lost (36" deep hole exposed.) c. None evident d. None observed e. None evident f. None significant observed g. None evident h. None evident i. None evident
4. General <ul style="list-style-type: none"> <li>a. Lateral Movement</li> <li>b. Vertical Alignment</li> <li>c. Horizontal Alignment</li> <li>d. Condition at Abutments and at Structures</li> <li>e. Indications of Movement of Structural Items</li> <li>f. Trespassing</li> <li>g. Instrumentation Systems</li> </ul>	4. a., b., c. Embankment & slopes generally irregular; embankment $\approx 2'$ lower than top of training walls rt. of spillway. d. Erosion & loss of soil at ends of training walls e. None observed f. Extensive foot traffic g. None evident

VISUAL INSPECTION CHECK LIST  
NATIONAL DAM INSPECTION PROGRAM

DAM: Massapoag Pond

DATE: August 22, 1978

SPILLWAY: \_\_\_\_\_

CHECK LIST	CONDITION
1. Approach Channel a. General Condition b. Obstructions c. Log Boom etc.	1.a. Walls in fair condition. Rt. wall has spalls and efflorescence. Lt. wall has spalls, eroded vert surface, exposed grab bars or reinforcing bars and efflorescence.
2. Weir a. Flashboards b. Weir Elev. c. Vegetation d. Seepage e. Rust or Stains f. Cracks g. Condition of Joints h. Spalls, Voids or Erosion i. Visible Reinforcement j. General Struct. Condition	b. None observed c. None 2.a. None observed b. 161+ c. None noted d. Visibility obscured e. N.A. timber f. N.A. timber g. N.A. timber h. N.A. timber i. N.A. timber j. Various timbers in weir and weir support are waterlogged. Some can be easily penetrated up to 3/4" with a geologist pick. Timber weir considered in fair condition.
3. Discharge Channel a. Apron b. Stilling Basin c. Channel Floor d. Vegetation e. Seepage f. Obstructions g. General Struct. Condition	3.a. Apron observed only in outlet area. b. None c. Natural stream bed, scattered rocks on surface. d. Trees and brush at edges of stream bed and on banks. e. None observed f. Minor obstructions including one tree across stream. g. Good struct. condition but see 4 walls.
4. Walls a. Wall Location _____ (1) Vegetation (2) Seepage or Efflorescence (3) Rust or Stains (4) Cracks (5) Condition of Joints (6) Spalls, Voids or Erosion (7) Visible Reinforcement (8) General Struct. Condition	4.a. (1) grass top of lt. abut. (2) Local efflorescence both walls. (3) None noted (4) Cracks both walls. (5) Good condition (6) Top of rt. wall spalled. Downstream end of lt. wall shows exposed rotted timbers. (7) None observed (8) Fair to good condition except rotted timbers in lt. wall. This area is in poor condition.

VISUAL INSPECTION CHECK LIST  
NATIONAL DAM INSPECTION PROGRAM

DAM: Massapoag Pond

DATE: August 22, 1978

SPILLWAY: \_\_\_\_\_

CHECK LIST	CONDITION
<p>5. Bridge</p> <p>a. General Struct. Condition</p>	<p>5.a. The bridge over the spillway is in fair struct. condition. The ends of the stringers are rotted. A few of the deck planks are missing. The entire struct. including railing needs painting.</p>

VISUAL INSPECTION CHECK LIST  
NATIONAL DAM INSPECTION PROGRAM

DAM: Massapoag Pond

DATE: August 22, 1978

OUTLET WORKS: \_\_\_\_\_

CHECK LIST	CONDITION
<ol style="list-style-type: none"> <li>1. Inlet               <ol style="list-style-type: none"> <li>a. Obstructions</li> <li>b. Channel</li> <li>c. Structure</li> <li>d. Screens</li> <li>e. Stop Logs</li> <li>f. Gates</li> </ol> </li> <li>2. Control Facility               <ol style="list-style-type: none"> <li>a. Structure</li> <li>b. Screens</li> <li>c. Stop Logs</li> <li>d. Gates</li> <li>e. Conduit</li> <li>f. Seepage or Leaks</li> </ol> </li> <li>3. Outlet               <ol style="list-style-type: none"> <li>a. Structure</li> <li>b. Erosion or Cavitation</li> <li>c. Obstructions</li> <li>d. Seepage or Leaks</li> </ol> </li> <li>4. Mechanical and Electrical               <ol style="list-style-type: none"> <li>a. Crane Hoist</li> <li>b. Hydraulic System</li> <li>c. Service Power</li> <li>d. Emergency Power</li> <li>e. Lighting</li> <li>f. Lightning Protection</li> </ol> </li> </ol>	<ol style="list-style-type: none"> <li>1. See spillway checklist</li> <li>2.a. Timber struct. Support of platform in poor condition. Ends of horiz. support rotted. Vertical supports indicate deterioration at waterline.               <ol style="list-style-type: none"> <li>b. None</li> <li>c. None</li> <li>d. 25" x 38" timber gate; gate appears waterlogged.</li> <li>e. None</li> <li>f. Small leaks at gate.</li> </ol> </li> <li>3.a. The gate outlets between the Rt. abut. wall and a waterlogged timber bulkhead. The floor is a concrete mat with indications of being in good condition.</li> <li>4. No mechanical or electrical items.</li> </ol>

VISUAL INSPECTION CHECK LIST  
NATIONAL DAM INSPECTION PROGRAM

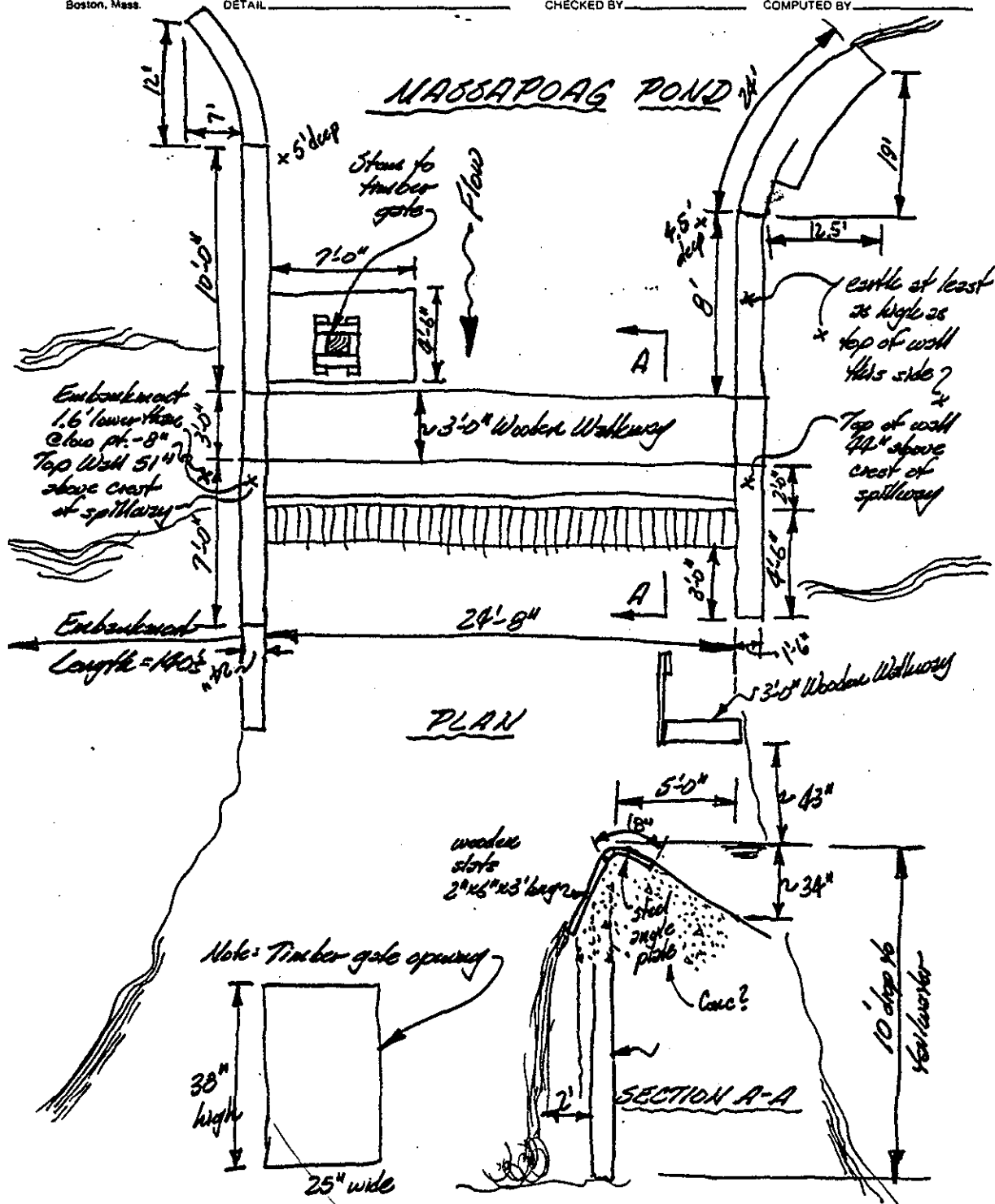
DAM: Massapoag Pond

DATE: August 22, 1978

HYDROLOGIC-HYDRAULIC CONSIDERATIONS: \_\_\_\_\_

CHECK LIST	CONDITION
1. Upstream Watershed a. Type of Terrain b. Hydrologic Controls	1. a. Gentle to rolling terrain-moderately hilly. b. Substantial upstream ponds & swampy area (Knopps Pond, Lost Lake, Whitney and Baddacock Ponds).
2. Reservoir a. Type of Terrain b. Development	2. a. Moderate to steep hills or sandy hills. b. More than 50 summer cottages and year-round homes along shoreline; also Camp Massapoag (YMCA).
3. Spillway a. Adjacent Low Points b. Spillway Approach (Slope) c. Spillway Discharge (Slope) d. Spillway Type	3. a. On right embankment small area 1.5' low, left okay. b. 4.5 ft. vert. on 13 ft. hor. c. 4 ft. vert. on 1.5 ft. hor. (2" x 6" wooden slats) d. Modified buttress cantilevered on wooden posts & beams.
4. Downstream Watershed a. Reach No. 1 (1) Control (Bridge, dam, culvert, etc.) (2) Channel Characteristics (3) Development (4) Visible Utilities (5) Special Problems (Hospital, etc.)  b. Reach No. 2 (1) (2) (3) (4) (5)	4. a. Lower Massapoag Pond (1) Outlet channel and Route 113 culvert. (2) Pond is about 1 mile in length with max. width of 800 ft. (3) Very sparse (4) None (5) None  b. Salmon Falls Brook (1) Channel, adjacent swampy area & Main St. culvert. (2) Channel has very mild slope with adjacent swampy areas. (3) No development within or adjacent to flood plain. (4) None (5) None





APPENDIX B

LIST OF AVAILABLE DOCUMENTS AND  
PRIOR INSPECTION REPORTS

Page No.

LIST OF AVAILABLE DOCUMENTS

C. M. Bacon, Contractor, correspondence to  
Cambridge YMCA

B-1

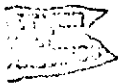
Report Upon Massapoag Pond Dam

B-4

PRIOR INSPECTION REPORTS

<u>DATE</u>	<u>BY</u>	
1. May 24, 1960	Middlesex County Engineer	B-8
2. October 17, 1973	Mass. Dept. of Public Works	B-10
3. November 17, 1973	Mass. Dept. of Public Works	B-14

C. M. BACON & SONS  
**CLARENCE M. BACON**  
*Architect and Builder*



A COMPLETE BUILDING SERVICE - SERVING THRUOUT  
NEW ENGLAND

ESTATE  
RENT EXCHANGE,  
S. ADJUSTMENTS,  
TOWN A SPECIALTY

RESIDENCE AND OFFICE  
NORTH CHELMSFORD, MASS.  
TELEPHONE LOWELL 1722 0482

CONSTRUCTION  
STORE FRONTS AND FIXTURES  
RESIDENTIAL AND COMMERCIAL  
GENERAL CONTRACTOR

March 5, 1949

Large Young Men's Christian Association  
Massachusetts Avenue  
Lynn, Massachusetts

TO: Glenn C. Fendayn

RE: Dam at Massapog

SIR:

As per our consultation of last week, I hereby submit the following:-

(A)- To rebuild coffer dam at old location with a plank spillway  
in center, using sand bag method and back filling at least 3'  
of all material would cost the sum of \$240.00.

(B)- If this is not done as a whole, add a total of \$110.00 to  
fixing or repairing hole (Item B) and replanking (Item E), as we  
have to install a temporary coffer dam to handle these items.

(C)- Repair hole at bottom of dam by holding water back and filling  
with granite and clay, well placed and compacted, would cost  
of \$180.00.

(D)- Reinforce top member of spillway by placing a steel beam along  
top of present timber, said beam to be set into concrete walls at  
least 6", being well pointed up after setting, and then  
put 3 blocks of timber and lag in place, would cost the sum of  
\$75.00.

(E)- Removal of present top walk timbers and placing one 10 x 12  
and second hand timber of good quality to carry gate house timber,  
in place and reinforcing gate house, would cost \$85.00.

(F)- To cover the face of the dam with new 3" spruce plank, well  
laid with 300 spikes and place new plank on gate would cost \$100.00.

giving a total of \$690.00.

Respectfully submitted,

APPENDIX B-1

C. M. BACON & SONS

BY: Clarence M. Bacon

OUR MOTTO - GOOD WORKMANSHIP + GOOD  
MATERIAL + FAIR PRICES - GOOD BUSINESS

## *E. M. Bacon and Sons*

### GENERAL CONTRACTORS

Forest Hill Road • Dunstable, Mass.

HARRY M. BACON

TEL. TYNGSBORO Niagara 9-6517

October 23, 1973

1 "DUB" BACON  
Dunstable Road  
Chelmsford, Mass.  
Phone 1-3402

E. W. BACON  
Ant Street  
Dunstable, Mass.  
Phone 9-5103

CLARENCE M. BACON  
Retired

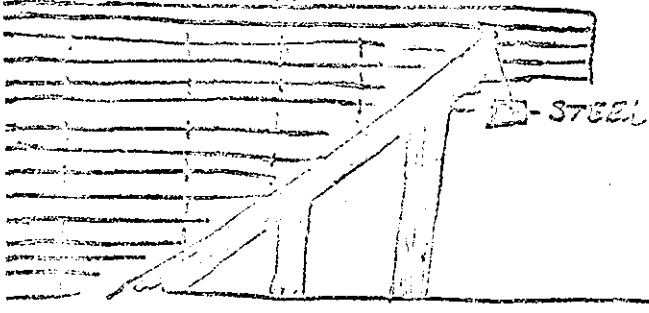
MRS. "PAT" DUCKINGHAM  
143 Old Westford Road  
Chelmsford, Mass.  
Phone 6-2401  
Clinical Office

nbridge Y.M.C.A.  
nbridge, Mass.

Repair work on dam at Lake Massapog, Dunstable, Mass. required removal of all wood from the left hand wall on the upper side of the dam and replacing the 6" x 6" post set into the concrete. We also removed gate and installed a new gate with a new post.

Material & Equipment	\$290.00
Labor - 88 hours @ \$7.50	660.00
Total	<u>\$950.00</u>

WEST WALL - CONCRETE POURED BEHIND ORIGINAL WOOD WALL



ALL OLD TIMBER REMOVED FROM CONCRETE ON LAKE SIDE  
NEW UPRIGHTS SET INTO CONCRETE.

WALL DOUBLE PLANKED WITH PLASTIC MEASURING  
BETWEEN PLANKS & TIED ONTO DAM FACE.

ENGINEERS

BOSTON, MASS.

J-MCC Dam Survey

GET-js

6/21/60

REPORT  
UPON  
MASSAPOAG POND DAM  
DUNSTABLE, MASSACHUSETTS

General

The Massapoag Pond Dam across Salmon Brook is located in Dunstable Township at Pond Street about 1700 yards south of State Route 113. The dam is of earth construction with a concrete spillway. The structure is about 200 ft. long and 12 ft. high. The 120 acre pond is used for recreation.

The spillway is about 25 ft. long and 8-1/2 ft. high. The depth of waterway opening is 4.1 ft. The structure is a trapezoidal type with a crest width of about 1 ft., the upstream face sloping about 1-1/2 to 1 and the downstream face on about a 1 to 3 slope. This downstream slope is for a depth below the crest of 3 ft. The surface then slopes upstream.

The embankment to the right of the spillway is about 150 ft. long. Its crest varies in elevation so that the lowest point is about 1.6 ft. lower than the top of the abutment walls. The indications are that this structure was a stone masonry dam and that the earth embankment section was recently constructed over it. The downstream slope is about 2-1/4 to 1 and the upstream slope is about 2-1/2 to 1.

There is a timber footbridge across the top of the spillway abutments. A wooden gatehouse is on the right end of the spillway. There is a gate of unknown size in the spillway under the gatehouse. Water flow conditions did not permit an examination of this gate at the time of the last inspection.

#### Conclusions and Recommendations

1. The existing potential spillway capacity of the dam together with the available storage in the pond is not sufficient to accommodate a Rare Flood as determined by the Kinnison-Colby Formula.
2. The crest of the embankment should be brought up to the level of the spillway abutments as an immediate repair.
3. The spillway capacity should be increased by increasing the height of the embankment and abutment walls by at least 2.5 ft. or by any other approved method.

#### Spillway Capacity and Flood Flows

The present capacity of the 25 ft. long spillway is estimated to be 345 cfs. (cubic feet per second). Only 2.5 ft. of the 4.1 ft. depth of spillway was considered effective due to the low crest of the right embankment. If the embankment were brought up to the level of the top of the spillway abutment walls, the capacity of the spillway would be 725 cfs. without provision for freeboard. The tributary drainage area above the dam is 11.83 square miles.

Runoff from about 47 percent of the drainage area was considered in computing the flood flow. The remaining 53 percent of the drainage area consists of considerable pond and marsh area which would provide much storage for and retard the runoff. The maximum expected flood flow is estimated from the Kinnison-Solby Formula (Rare Floods) as 2900 cfs. This rate of flow would be about four times what the spillway would be capable of carrying after the embankment had been brought up to the top of the spillway abutment walls.

If the spillway abutments and embankment crest were raised 2.5 ft., the head on the spillway of 6.5 ft. together with the storage in the pond would take the flow of 2900 cfs.

#### Stability and Repairs

The stability of the structure appears adequate. The earth embankment should in any event be brought up to the level of the top of the spillway abutment walls. When increasing the height of the dam 2.5 ft., the material should be well compacted, the top width of embankment made not less than 10 ft. and the embankment slopes not steeper than 2-1/2 to 1 on the upstream side and not steeper than 2 to 1 on the downstream side. The abutment walls should be raised accordingly and extensions made to the wasteway channel walls.

By: Gordon E. Thomas  
Gordon E. Thomas  
Project Engineer



Location: Approximately 150 feet downstream at an existing dam between Massapoag Pond and Lower Massapoag Pond in Dunstable, Mass.

Facilities  
Affected:

Below design high water elev. - 200

90 Cottages  
1 house  
1 Massapoag Camp  
1 Day Camp  
1100 feet of Hall St.  
200 feet of Curve St.  
150 feet of Route 140

Below design high water elev. - 180

77 Cottages  
1 Massapoag Camp  
1 Day Camp  
200 feet of Massapoag Rd.  
150 feet of Pond St.

Below design high water elev. - 195

87 cottages  
1 house  
1 Massapoag Camp  
1 Day Camp  
400 feet of Hall St.

Below design high water elev. - 175

72 Cottages  
1 Massapoag Camp  
1 Day Camp

Below design high water elev. - 190

87 Cottages  
1 house  
1 Massapoag Camp  
1 Day Camp  
For elevations higher than 185, Massapoag Rd. and Pond St. are assumed abandoned. Bridge St., Wharf Rd. and Groton Road (all gravel roads) are assumed abandoned for all elevations. For elevations less than 185 it probably would be economically feasible to raise short sections of Massapoag Rd. and Pond St.

Below design high water elev. - 170

38 Cottages  
1 Massapoag Camp

Below design high water elev. - 165

3 cottages

Below design high water elev. - 185

82 cottages  
1 Massapoag Camp  
1 Day Camp  
200 feet of Massapoag Rd.  
1300 feet of Pond St.

Geologic

Conditions: Both abutments are outwash sand and gravel. The foundation is outwash sand and gravel over glacial till or bedrock which is probably shallow. There are no apparent leakage problems at the present water level being maintained in Massapoag Pond. Borrow material for dam construction is available on site.

Dunstable

DAM NO. C-4

Outlet Massapoag Pond  
off Pond Street

STREAM Salmon Brook

MIDDLESEX COUNTY ENGINEERING DEPARTMENT  
CAMBRIDGE, MASSACHUSETTS

D A M I N S P E C T I O N R E P O R T

Cambridge YMCA

Cambridge, Mass.

International Paper Box

Place Nashua, N. H.

Use Recreation

Machine Co.

by Joseph S. Krzywicki

Date May 24, 1960

Dam Earth fill (see note)

Condition Good

Length 24.9 ft.

Ht. to Top Emb. Section 4.1 ft.

ds in Place none

Ht. of

Recent Repairs

Good

eeded None visible

Length

Height 12 ft.

Type

airs Fill added (see note)

Fair

aded Remove trees, build up low areas on top embankment

Number One

Size Unknown

Types Unknown

irs None visible

Not visible

ded Not able to be observed

illed Description and Location on Back of Sheet

None visible

24, 1960

Mass. P.E. 10430

Signature Inspecting Engineer

- See Back of Sheet

Engineer, Metcalf & Eddy

Title

arks and Characteristics on Back of Sheet

APPENDIX B-8

ne visible.

D ACTION: Re inspection of spillway during low water period.

See attached report.

MARKS: There are indications that the original dam was constructed  
cone masonry and that it has been raised by the addition of earth fill.

DESCRIPTION OF DAM  
DISTRICT #4

Designed by FRANCIS H. PARÉ & ADAM Z. PIZAN  
11-14-73

Dam No. 4-9-81-2  
City/Town DUNSTABLE  
Name of Dam MASSAPOG POND DAM

DUNSTABLE ROD & GUN CLUB, DUNSTABLE, MASS. 01827

Location: Topo Sheet No. 25A  
Provide 8 1/2" x 11" in clear copy of topo map with location of Dam clearly indicated.

Year built: UNKNOWN Year/s of subsequent repairs 10-17-73

Purpose of Dam: Water Supply \_\_\_\_\_ Recreational ☒  
Irrigation \_\_\_\_\_ Other \_\_\_\_\_

Drainage Area: 11.83 SQ. Mi. 7571.20 ACRES.

Normal Ponding Area: 120 acres; Ave Depth 5'  
Impoundment: 200 MIL. gals; 600 acre ft.

No. and type of dwellings located adjacent to pond or reservoir  
e.g., summer homes etc. 87 COTTAGES, 1 HOUSE, 1 CAMP, 1 DAY CAMP

Dimensions of Dam: Length 25' Max. Height 9'  
Slopes: Upstream Face 4:1  
Downstream Face 2  
Width across top 15'

Classifications of Dam by Materials:

Earth ☒ Conc. Masonary \_\_\_\_\_ Stone Masonary \_\_\_\_\_  
Timber \_\_\_\_\_ Rockfill \_\_\_\_\_ Other \_\_\_\_\_

- Description of present land usage downstream of dam: 90% rural;  
10% urban  
Is there a storage area or flood plain downstream of dam which could accommodate the impoundment in the event of a complete dam failure  
no \_\_\_\_\_ yes ☒

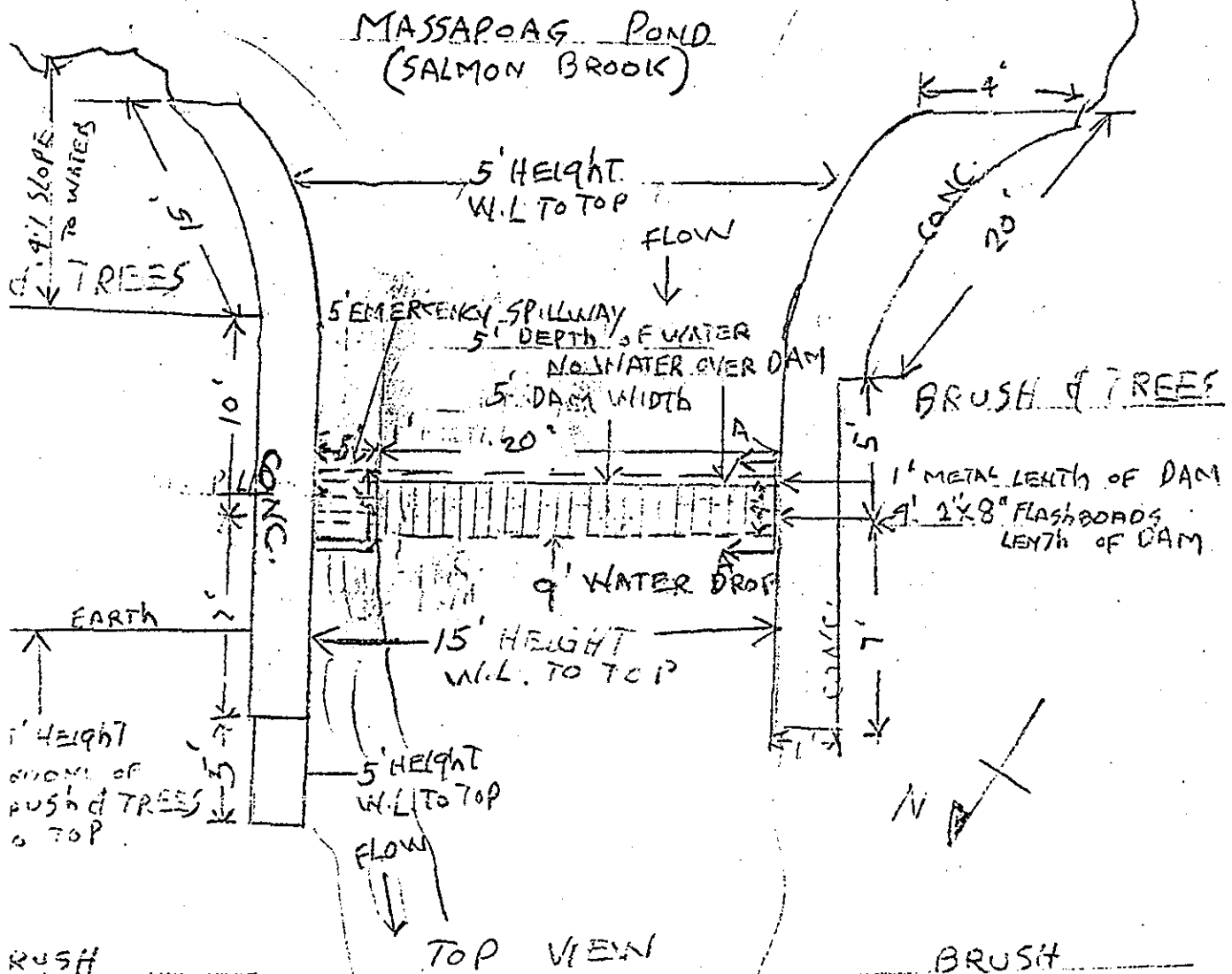
DAM NO. 4-9-81-2

sk to life and property in event of complete failure.

No. of people NONE .  
 No. of homes " .  
 No. of businesses NONE .  
 No. of industries " .  
 No. of utilities " .  
 Railroads NONE .  
 Other dams " .  
 Other  .

Type   
 Type

attach sketch of dam to this form showing section and plan 8 1/2" X 11" Sheet.



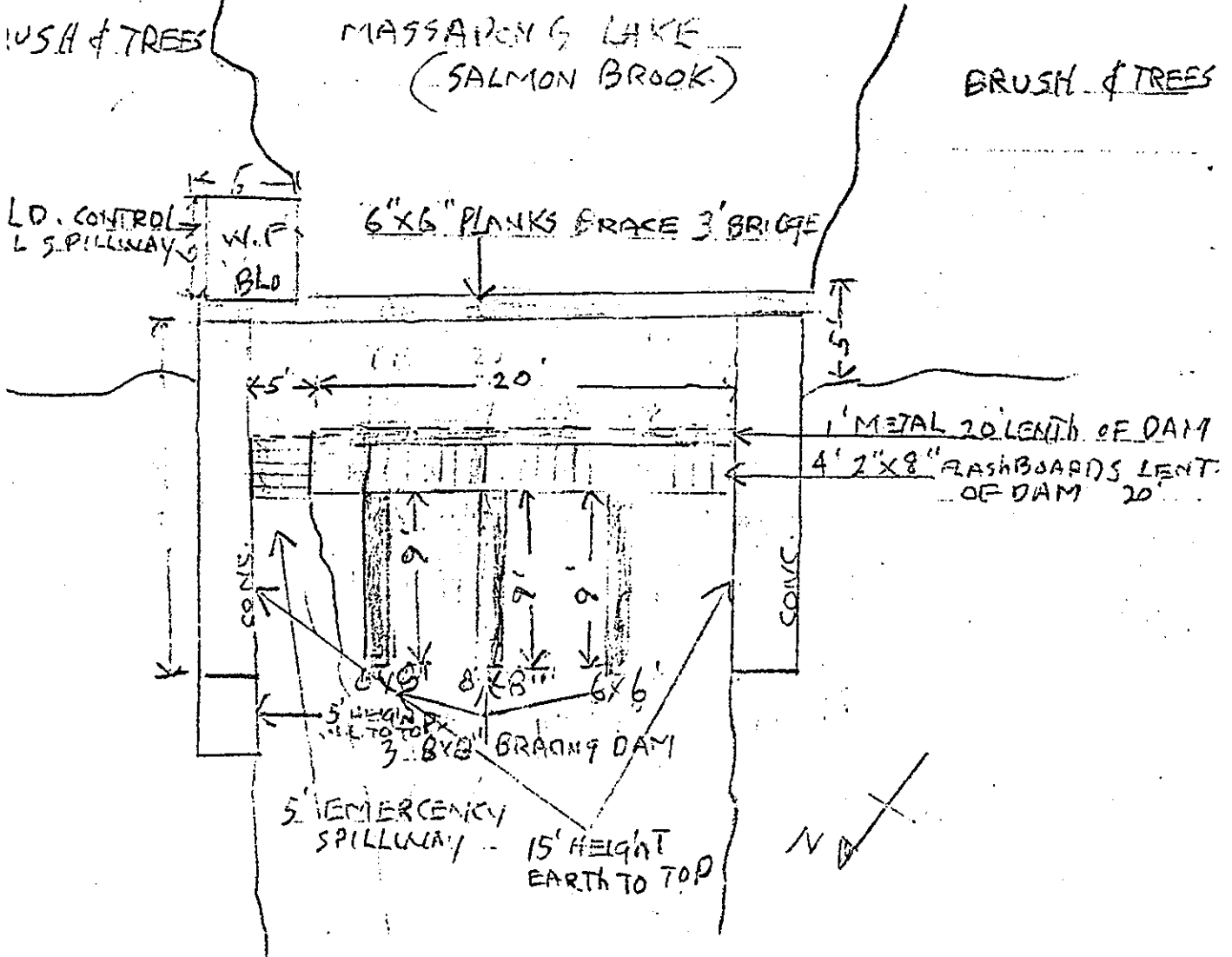
DAM NO. 4-9-81-2

ask to life and property in event of complete failure.

No. of people NONE °  
 No. of homes " °  
 No. of businesses NONE °  
 No. of industries " °  
 No. of utilities " °  
 Railroads NONE °  
 Other dams " °  
 Other \_\_\_\_\_ °

Type \_\_\_\_\_  
Type \_\_\_\_\_

attach sketch of dam to this form showing section and plan 8½"X11" Sheet.



FRONT VIEW  
SKETCH NOT TO SCALE

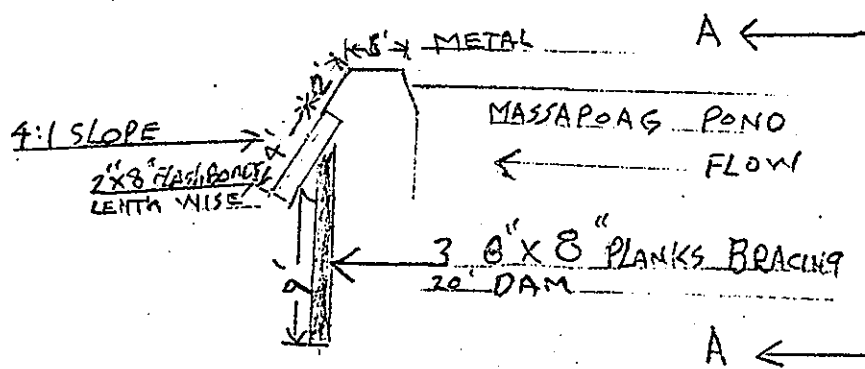
DAM NO. 4-9-81-2

sk to life and property in event of complete failure.

No. of people NONE  
No. of homes "  
No. of businesses NONE  
No. of industries "  
No. of utilities "  
Railroads NONE  
Other dams "  
Other "

Type \_\_\_\_\_  
Type \_\_\_\_\_

attach sketch of dam to this form showing section and plan 8 $\frac{1}{2}$ "x11" Sheet.



X SECTION

SKETCH NOT TO SCALE

## INSPECTION REPORT - DAMS AND RESERVOIRS

Location: City/Town DUNSTABLE  
 Name of Dam MASSAPOAG POND DAM

Dam No. 4-9-81-2  
ADAM Z. PIZAN, F.  
 Inspected by FRANCIS H. PARE

Date of Inspection 11-17-73

Owners: \_\_\_\_\_ per: AUSSEBENS Prev. Inspection \_\_\_\_\_

Reg. of Deeds \_\_\_\_\_ Pers. Contact \_\_\_\_\_  
DUNSTABLE ROP & GUN CLUB DUNSTABLE MASS 01827 649-7273  
 Name \_\_\_\_\_ St. & No. \_\_\_\_\_ City/Town \_\_\_\_\_ State \_\_\_\_\_ Tel. No. \_\_\_\_\_

Name \_\_\_\_\_ St. & No. \_\_\_\_\_ City/Town \_\_\_\_\_ State \_\_\_\_\_ Tel. No. \_\_\_\_\_

Name \_\_\_\_\_ St. & No. \_\_\_\_\_ City/Town \_\_\_\_\_ State \_\_\_\_\_ Tel. No. \_\_\_\_\_

Detaker: (if any) e.g. superintendent, plant manager, appointed by  
 Lessee owner, appointed by multi owners.

WARD SMALL HALL ROAD DUNSTABLE MASS 01827 649-7273  
 Name \_\_\_\_\_ St. & No. \_\_\_\_\_ City/Town \_\_\_\_\_ State \_\_\_\_\_ Tel. No. \_\_\_\_\_

No. of Pictures taken 3

Degree of Hazard: (if dam should fail completely)\*

1. Minor ✓ 2. Moderate \_\_\_\_\_  
 3. Severe \_\_\_\_\_ 4. Disastrous \_\_\_\_\_

\*This rating may change as land use changes (future development)

Outlet Control: Automatic \_\_\_\_\_ Manual ✓

Operative ✓ yes: \_\_\_\_\_ no: \_\_\_\_\_

Comments: FLASHBOARDS CONTROL EMERGENCY SPILLWAY

Upstream Face of Dam: \_\_\_\_\_ Condition: \_\_\_\_\_

1. Good ✓ 2. Minor Repairs \_\_\_\_\_  
 3. Major Repairs \_\_\_\_\_ 4. Urgent Repairs \_\_\_\_\_

Remarks: DAM REPAIRED 10-17-73



Comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Spillway: Condition: 1. Good ✓ 2. Minor Repairs \_\_\_\_\_

3. Major Repairs \_\_\_\_\_ 4. Urgent Repairs \_\_\_\_\_

Comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

level @ time of inspection 2 ft. above \_\_\_\_\_ below ✓

top of dam \_\_\_\_\_ Principal spillway ✓

other \_\_\_\_\_

ry of Deficiencies Noted:

with (Trees and Brush) on Embankment \_\_\_\_\_

mal Burrows and Washouts \_\_\_\_\_

age to slopes or top of dam \_\_\_\_\_

cked or Damaged Masonry \_\_\_\_\_

dence of Seepage \_\_\_\_\_

dence of Piping \_\_\_\_\_

sion \_\_\_\_\_

ks \_\_\_\_\_

sh and/or debris impeding flow \_\_\_\_\_

gged or blocked spillway \_\_\_\_\_

or \_\_\_\_\_

REPAIRS ON DAM COMPLETED 10-17-73.  
TER BUILDING UP, AS OF INSPECTION  
1E, 11-17-73. FLASHBOARDS 2"X8" 5X5',  
WOOD BEAMS BRACING SPILLWAY, 8"X8" 9' HEIGHT  
1"X8" FLASHBOARDS 4', 4:1 SLOPE DIFFERENT  
ATION, 20' LENGTH.

---

Overall Condition:

1. Safe ✓
2. Minor repairs needed \_\_\_\_\_
3. Conditionally safe - major repairs needed \_\_\_\_\_
4. Unsafe \_\_\_\_\_
5. Reservoir impoundment no longer exists (explain)  
Recommend removal from inspection list NO

APPENDIX C

SELECTED PHOTOGRAPHS OF PROJECT

Page No.

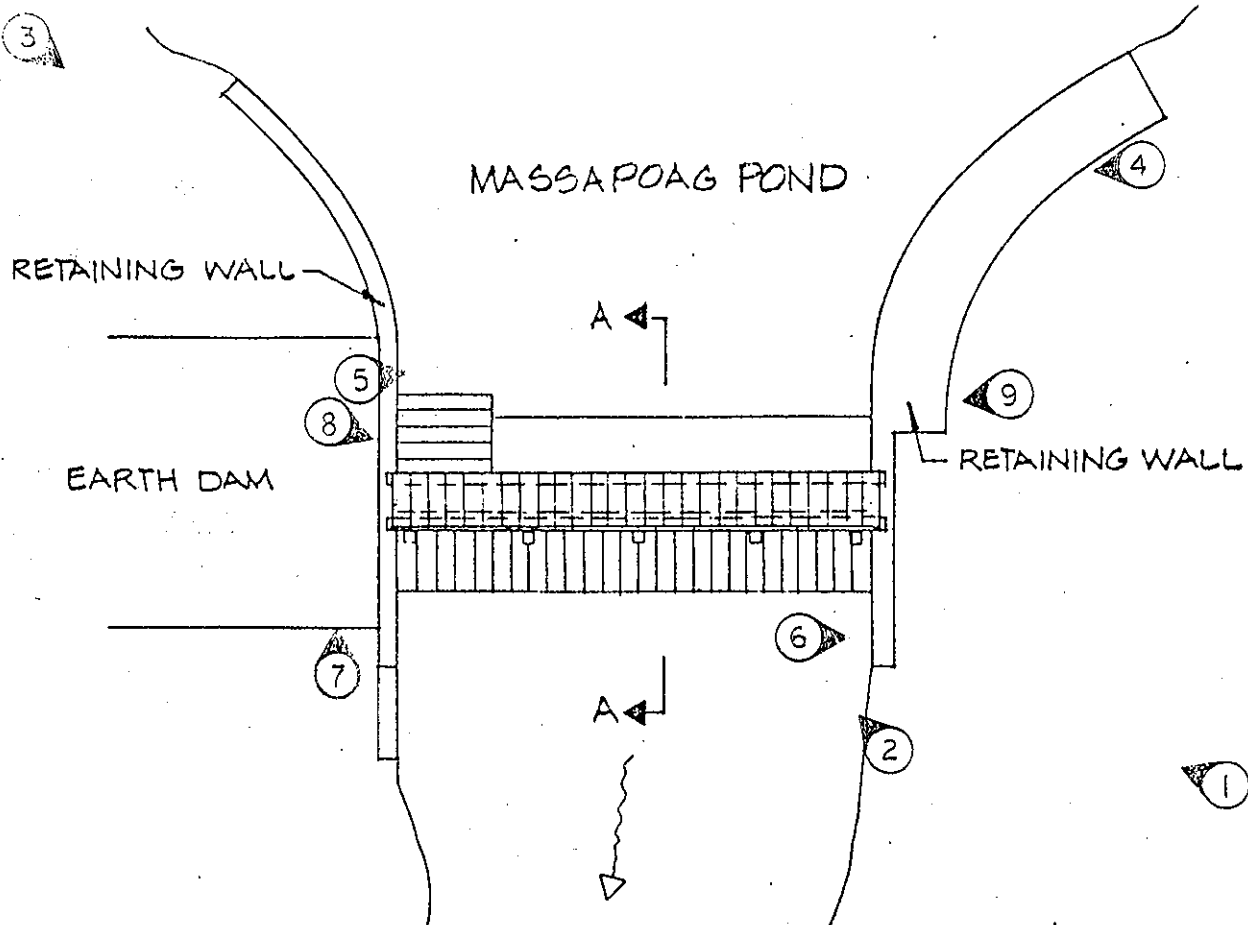
LOCATION PLAN

Location of Photographs

C-1

PHOTOGRAPHS

<u>No.</u>	<u>Title</u>	<u>Page No.</u>
1.	Overview of Dam	Follows Table of Contents
2.	Downstream Face of Dam	C-2
3.	View of Dam From Upstream Right Embankment	C-2
4.	Approach Channel, Right Training Wall	C-3
5.	Approach Channel, Left Training Wall	C-3
6.	Deteriorated Timbers at Left Side of Spillway, Downstream of Crest	C-4
7.	Missing Stone in Downstream Right Sidewall of Spillway	C-4
8.	Reservoir Drain Gate Operator and Footbridge From Right Abutment	C-5
9.	Reservoir Drain Gate Operator and Footbridge From Left Abutment	C-5



PLAN

CAMP DRESSER & MCKEE INC.  
BOSTON, MASSACHUSETTS

U.S. ARMY ENGINEER DIV. NEW ENGLAND  
CORPS OF ENGINEERS  
WALTHAM, MASS.

NATIONAL PROGRAM OF INSPECTION OF NON FED. DAMS

# MASSAPOAG DAM PLANS & SECTION

MASSAPOAG POND

MASSACHUSETTS

SCALE: NONE

DATE: AUG. 1978





2. VIEW OF DOWNSTREAM FACE OF DAM.



3. VIEW OF DAM FROM UPSTREAM RIGHT EMBANKMENT.





4. APPROACH CHANNEL RIGHT TRAINING WALL.



5. APPROACH CHANNEL LEFT TRAINING WALL.



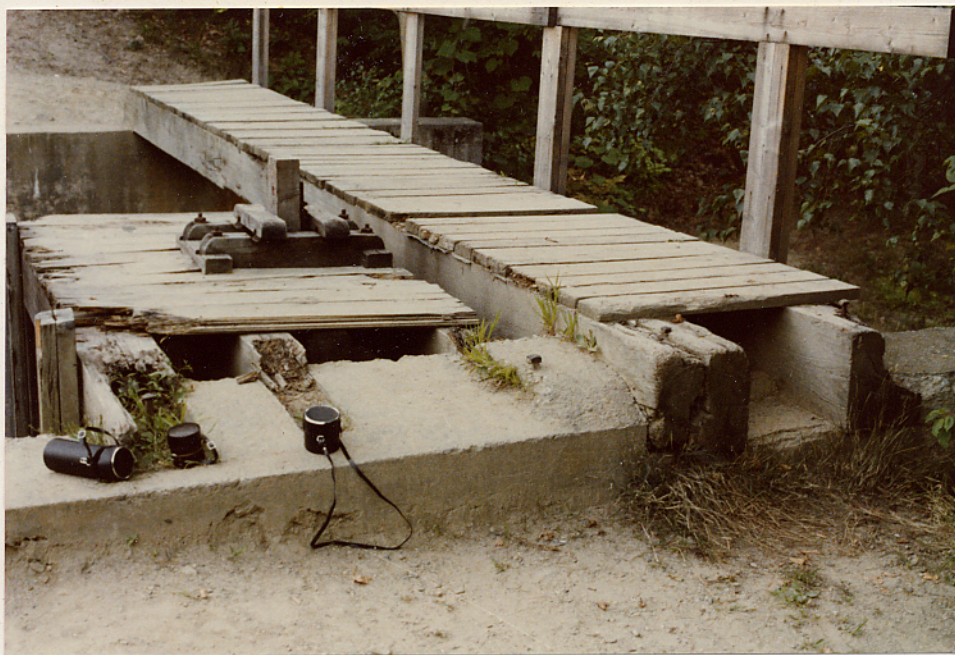


6. DETERIORATED TIMBERS AT LEFT SIDE OF SPILLWAY DOWNSTREAM OF CREST.



7. MISSING STONE IN DOWNSTREAM RIGHT SIDE WALL OF SPILLWAY.





8. RESERVOIR DRAIN GATE OPERATOR AND FOOTBRIDGE FROM RIGHT ABUTMENT.



9. RESERVOIR DRAIN GATE OPERATOR AND FOOTBRIDGE FROM LEFT ABUTMENT.



APPENDIX D  
OUTLINE OF DRAINAGE AREA AND  
HYDRAULIC COMPUTATIONS

Page No.

OUTLINE OF DRAINAGE AREA

Drainage Area Map	1
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COMPUTATIONS

Elevations; Surface Areas; and Storage Capacities	2
Size Classification; Hazard Potential	3
Test Flood; Drainage Area; and 100-Year Flood	
Determination	4
Dam & Spillway Rating Curve	5
Surcharge Storage Routing	6
Dam Failure Analysis - Massapoag Pond	7-12
Routing Analysis - Lower Massapoag Pond	13-15



**CAMP DRESSER & McKEE Inc.**  
Consulting Engineers  
Boston, Mass.



MASSAPOAG POND  
DAM  
DRAINAGE AREA MAP  
SCALE: 1" = 4000'

APPENDIX D-1

### ELEVATIONS

There is no set crest elevation for Massapoag Pond Dam.  
USGS Quad: NASHUA SOUTH, MA.-N.H., 1965 shows the  
pond elev. @ Elev. 161.0 - according to equal crest elev.

CREST ELEV. = 161.0  
TOE OF SPILLWAY = 161 - 10.0 = 151.0  
TOP OF LEFT ABUTMENT WALL = 161 + 3.67 = 164.67  
TOP OF LEFT EMBANKMENT = 161 + 3.67 = 164.67  
TOP OF RIGHT ABUTMENT WALL = 161 + 4.25 = 165.25  
TOP OF RIGHT EMBANKMENT: VARIES FROM 165.25 - 0.67 = 164.58 @ ABUTMENT TO 165.25 - 1.6 = 163.65 @ ABOUT THE CENTER  
BOTTOM OF WOODEN WALKWAY = 161 + 3.55 = 164.55  
TOP OF WOODEN WALKWAY = 161 + 3.55 + 0.5 = 165.05

### SURFACE AREAS

POUND @ Elev. 161.0 = 109.7 acres } Elev. 163.65 = (165.3 - 109.7) / 9  
Elev. 170.0 = 165.3 " } x 2.65 + 109.7 = 1726.0  
Elev. 180.0 = 214.0 " } Elev. 164.74 = (165.3 - 109.7) / 9  
x 3.74 + 109.7 = 132.5

### STORAGE CAPACITIES

At Crest Elev. 161.0 = 109.7 x 10 x 1/3 = 366 ac.-ft.  
@ Elev. 170.0 = 366 + ((109.7 + 165.3) / 2) x 9 = 1,604 ac.-ft.  
@ Elev. 180.0 = 1604 + ((165.3 + 214.0) / 2) x 10 = 3500 ac.-ft.  
@ Top of Dam (Elev. 163.65) = (1604 - 366) / 9 x 2.65 + 366 = 730 ac.-ft.  
@ Top of Left Abutment (Elev. 164.67)  
= (1604 - 366) / 9 x 3.67 + 366 = 870 ac.-ft.  
at test flood (Elev. 164.74)  
= (1604 - 366) / 9 x 3.74 + 366 = 880 ac.-ft.

### SIZE CLASSIFICATION

HYDRAULIC HEIGHT: Toe of Spillway to top of Spillway  
Wingwalls = 150'-6"

STORAGE CAPACITIES: @ Top of Dam (El. 163.65) = 730 ac-ft  
@ Top of Abutment (El. 164.67) = 870 ac-ft.

∴ SIZE CLASSIFICATION IS SMALL

### HAZARD POTENTIAL

DEQE has rated the degree of Hazard (if the dam should fail completely) as being minor.

A review of the downstream conditions based on the USGS Gauging is summarized in the following table.

REACH NO.	DOWNSTREAM CONTROL	LENGTH (ft)	DEGREE OF DEVELOPMENT
1	Pleasant St.	5,200	None
2	Main St.	2,700	None
3	Ridge Rd.	11,000	None
4	Scarles Rd.	4,000	None
5	East Dunstable Rd.	3,800	Slight Residential
6	Northeastern Blvd.	4,000	Moderate Residential
7	—	5,000	City of Nashua
35,700' = 6.8 miles			

The 1st Reach between the damsite and Pleasant St. is Lower Massapeag Pond. Much flood plain storage is available within Reaches 1-4.

On the basis of the above, the hazard is considered a low-significant: damages to roads, bridges, and utilities.

## TEST FLOOD

Hazard SIGNIFICANT & Size SMALL  $\rightarrow$  TEST FLOOD = 100-YR to  $\frac{1}{2}$  PMF

Since the hazard is a low-significant, use 100-YR.

## DRAINAGE AREA

From USGS Quads: 13.56 mi<sup>2</sup>

The sideslopes into the watershed are moderately steep. However, the series of Lakes, Ponds, Swamps, and Brooks which drain the basin are quite flat. Surface water and swamps have been estimated to be ~ 53% of the drainage area.

## 100 YEAR FLOODS

A. Johnson & Esker Method:

$$P_{100} = 0.260 A^{0.94} S^{0.167} p^{4.08}$$

where A = Drainage Area, sq. mi.  
S = Slope of Stream, ft./mi.  
p = Mean Annual Precipitation, ft.

Main Channel Slope:  $L_{TOTAL} = 40,600'$ ;  $L_{85\%-10\%} = 30,450'$   
 $= 5.77$  mi.

$$\text{Elev. @ } 85\% L = 305$$

$$\text{Elev. @ } 10\% L = -161$$

$$\frac{1414 \text{ ft.}}{5.77 \text{ mi.}} = 25 \text{ ft./mi.}$$

$$A = 13.56 \text{ mi}^2$$

$$p = 42" = 3.5$$

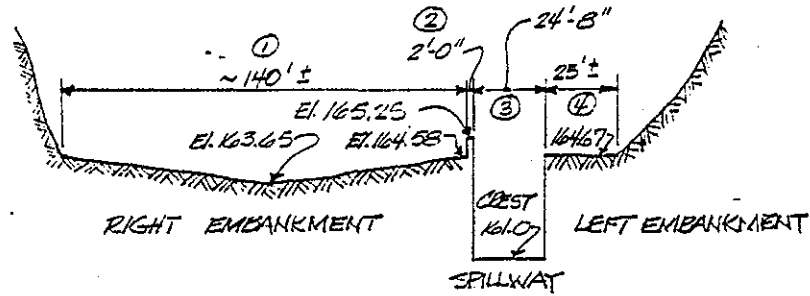
$$P_{100} = 0.26 (13.56)^{0.94} (25)^{0.167} (3.5)^{4.08} = \underline{913 \text{ cfs}}$$

B. USGS Water Resources Invest. 77-37 METHOD:

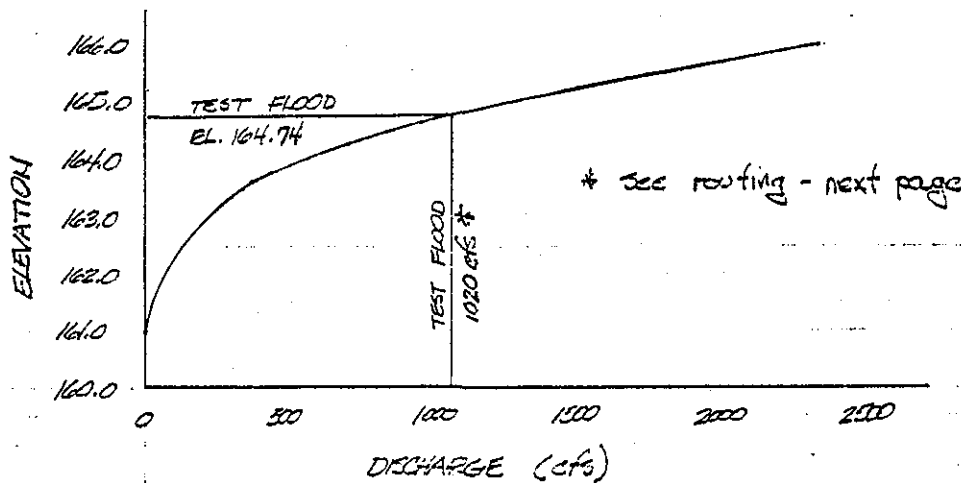
$$\text{for Eastern Mass. } Q_{100} = 53.86 A^{.507} S^{.272}$$

$$= 53.86 (13.56)^{.507} (25)^{.272} = \underline{1060 \text{ cfs}}$$

METHODS A & B compare well, use 1060 cfs for TEST FLOOD  
as it is more conservative



W.S. ELEV.	SECT. ① C=2.5	SECT. ② C=3.0	SECT. ③ C=3.5	SECT. ④ C=2.5	TOTAL FLOW
161.00	-	-	0	-	0
163.65	0	-	372	-	372
164.67	350	-	607	0	957
165.25	708	0	757	28	1,493
166.00	1261	4	965	96	2,326



STAGE - DISCHARGE RELATIONSHIPS

SURCHARGE - STORAGE ROUTING

$$Q_{P1} = 1,060 \text{ cfs}$$

$$\begin{aligned} \text{Surcharge Ht}_1 &= 164.61 + (1060 - 957) / (1473 - 957) \times (165.25 - 164.61) \\ &= 164.61 + (0.1922) (0.58) = 164.61 + 0.11 = 164.78 \end{aligned}$$

$$\begin{aligned} \text{STOR}_1 @ \text{El. } 164.78 &= (1604 - 366) / 9 \times (164.78 - 161.0) \\ &= 1238 / 9 \times 3.78 \\ &= 137.56 \times 3.78 = 520 \text{ ac.-ft.} \end{aligned}$$

$$\text{STOR}_1 = 520 / (53.3 \times 13.56) = 0.72 \text{ inches}$$

$$Q_{P2} = 1060 \times (1 - 0.72/6) = 933 \text{ cfs}$$

$$\begin{aligned} \text{Surcharge Ht}_2 &= 163.65 + (933 - 372) / (957 - 372) \times (1.02) \\ &= 163.65 + (0.96) (1.02) = 163.65 + 0.98 = 164.63 \end{aligned}$$

$$\begin{aligned} \text{STOR}_2 @ \text{El. } 164.63 &= (1604 - 366) / 9 \times (164.63 - 161.0) \\ &= 1238 / 9 \times 3.63 \\ &= 500 \text{ ac.-ft.} \end{aligned}$$

$$\text{AVE. STOR.} = (520 + 500) / 2 = 510 \text{ ac.-ft.}$$

$$\begin{aligned} \text{Surcharge Ht}_3 @ \text{AVE. STOR. (510 ac.-ft.)} &= (510) / (1604 - 366) \times 9 + 161.0 \\ &= 510 / 1238 \times 9 + 161.0 \\ &= 0.412 \times 9 + 161.0 = 3.74 + 161.0 = 164.74 \end{aligned}$$

$$\begin{aligned} Q_{P3} @ \text{El. } 164.74 &= (164.74 - 164.61) / (165.25 - 164.61) \\ &\quad \times (1473 - 957) + 957 \\ &= 0.07 / 0.58 \times 536 + 957 \\ &= 64.7 + 957 = 1022 \text{ cfs} \end{aligned}$$

$$\text{Say } 1020 \text{ cfs}$$

Dune Failure Analysis

$$Q_{14} = \frac{E}{37} (140')^2 \cdot 1.5 = 1.5$$

pressure that 40% of 140 surface of  
dune is 15. Assume that dune can

$$Q_{14} = \frac{E}{37} (140' \cdot 0.4) \cdot 2.2 (9.15')^2 = 2922 \text{ cfs}$$

only go down to Elev. 154 (Lower  
Masspess Road level) which is 154.2 ft  
below pond bottom @ spillway

We will assume that total contents  
of Masspess Road (930 ft<sup>2</sup>) is  
spilled here because with  $\Delta$  topographic  
peak flow occurs at  $\frac{T}{3}$

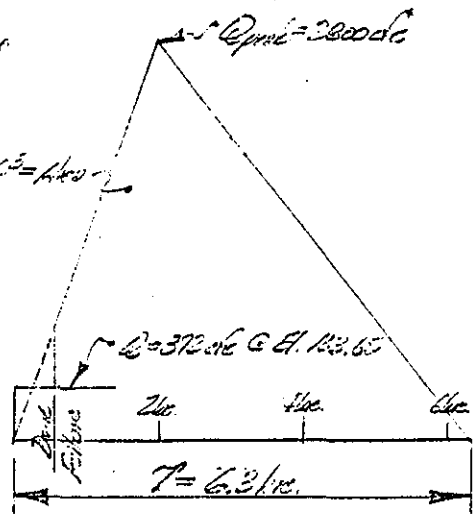
$$\text{Then } t_a = 163.65 - 154 = 9.65 \text{ ft.}$$

$$720 \text{ ft}^2 = 31,779,300 \text{ ft}^3 = 140 \text{ ft}$$

$$\frac{T}{3} (2920 \text{ cfs}) = 31,779,300 \text{ ft}^3$$

$$T = 6.31 \text{ hr} = 378.6 \text{ min.}$$

$$\text{say } T = 6 \text{ hrs @ } 360 \text{ min.}$$

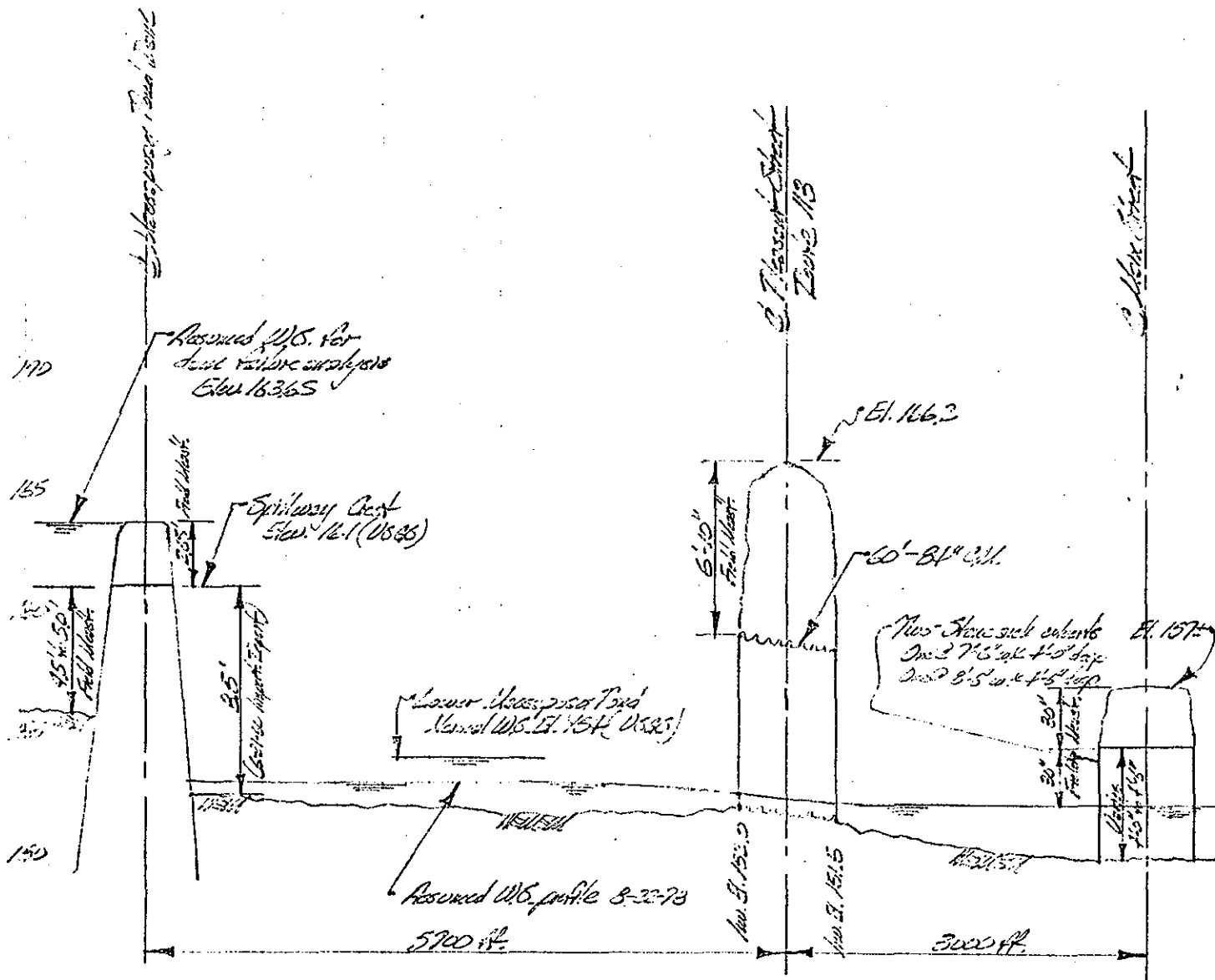


Consider volume of flow

passed flow break with time

Time	Inflow	Cumulative Inflow	Water Surf. Elev. Masspess Road
0	0	0	163.65
1 hr	1400 cfs	2,520,000 ft <sup>3</sup>	163.28
2 hr	2800	10,080,000	161.99
3	2150	18,890,000	160.40
4	1500	25,360,000	159.24
5	840	29,772,000	
6	160	31,603,000	
6.31	0	31,779,300	





Determine capacity of 60" dia. concrete Pressure Pipe

assume  $n = 0.013$  and  $S = 0.010$ , then  $Q_{0.1} = 330 \text{ cfs}$   $V = 3.90 \text{ fps}$   
surge capacity  $\frac{V^2}{2g} = 1.330'$

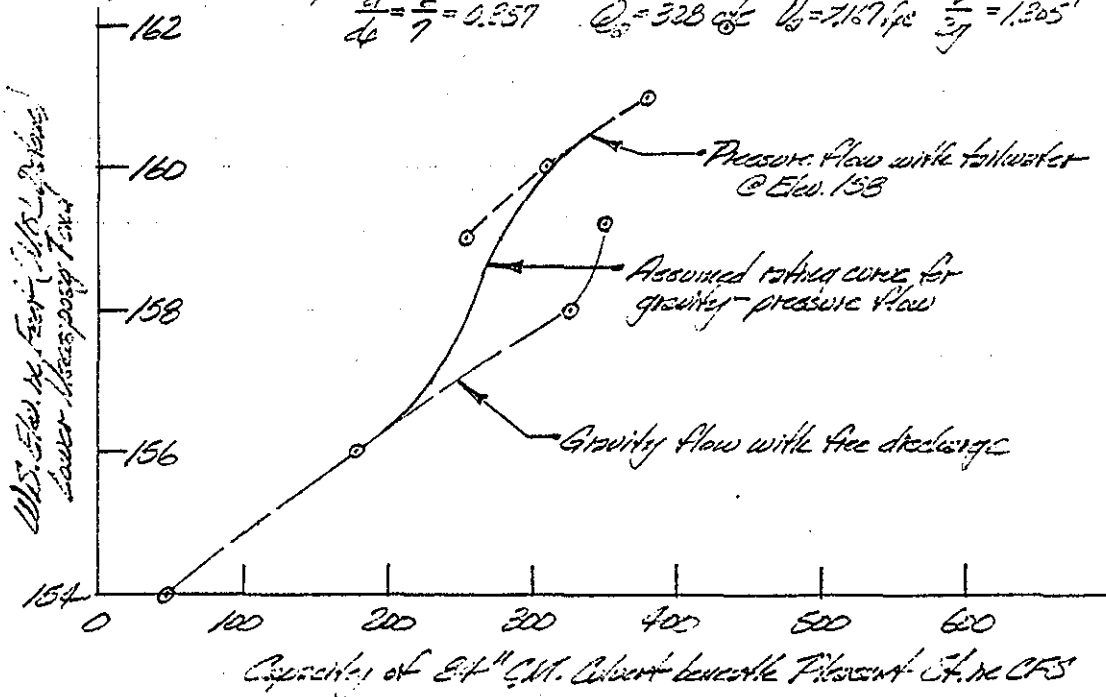
151-158 = 7.0'  $Q = 330 \text{ cfs}$   
150-158 = 8.0'  $Q = 340 \text{ cfs}$   
149-158 = 9.0'  $Q = 355 \text{ cfs}$   
148-158 = 10.0'  $Q = 425 \text{ cfs}$

From "Handbook of Steel Drains and  
Highway Construction Products" by AISC  
Memograph on Pg. 114

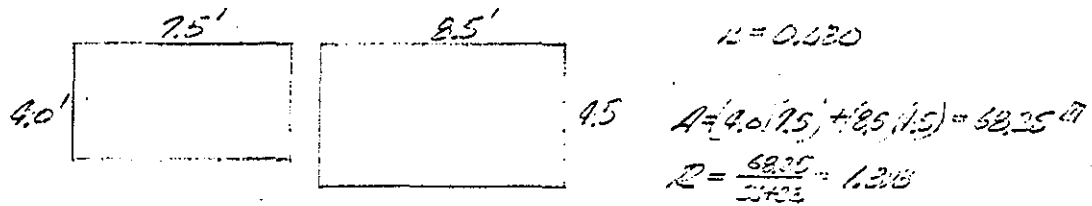
If U.S. W.S. @ E. 154,  $\frac{d}{D} = \frac{2}{7} = 0.286$   $Q_s = 19.3 \text{ cfs}$   $V_s = 5.25 \text{ fps}$   $\frac{V_s^2}{2g} = 0.12'$

If U.S. W.S. @ E. 156,  $\frac{d}{D} = \frac{4}{7} = 0.571$   $Q_s = 17.2 \text{ cfs}$   $V_s = 7.15 \text{ fps}$   $\frac{V_s^2}{2g} = 0.90'$

If U.S. W.S. @ E. 158,  $\frac{d}{D} = \frac{6}{7} = 0.857$   $Q_s = 32.8 \text{ cfs}$   $V_s = 7.17 \text{ fps}$   $\frac{V_s^2}{2g} = 1.305'$



Calculate capacity of Main Street sewer



$$Q = (68.25 \text{ ft}^2) \left( \frac{1.49}{0.030} \right) (1.26)^{2/3} (5)^{1/2} = 4216.332 \text{ cfs}$$

$$i \cdot S = 2.0' \cdot 50' = 0.040,$$

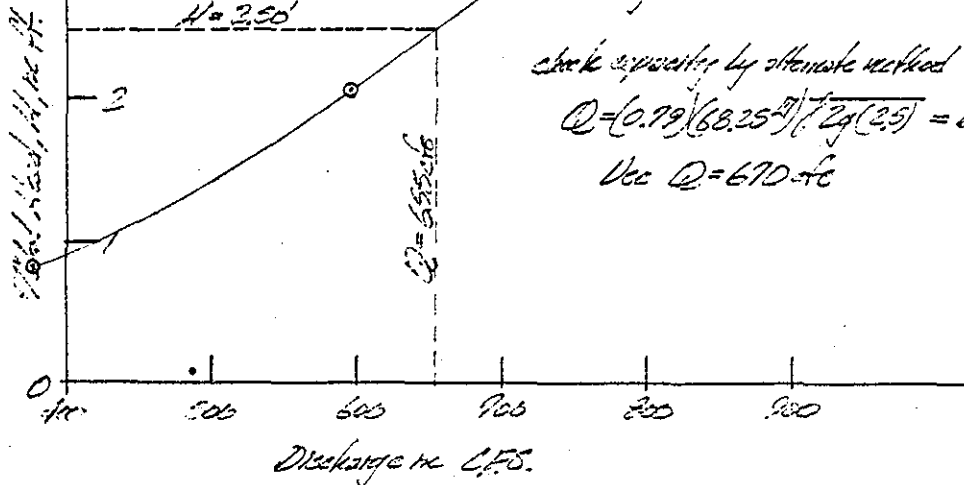
$$Q = 8433 \text{ cfs} \quad V_{\text{ave}} = 12.36 \text{ fps} \quad \frac{V^2}{2g} = 3.37' \quad H = 0.2 \frac{V^2}{2g} + 0.7 \frac{V^2}{2g} + 5 = 0.9(3.37) + 5.0 = 4.18'$$

$$i \cdot S = 1.5' \cdot 50' = 0.030,$$

$$Q = 730 \text{ cfs} \quad V_{\text{ave}} = 10.70 \text{ fps} \quad \frac{V^2}{2g} = 1.773' \quad H = 1.60 + 1.5 = 3.10'$$

$$i \cdot S = 1.0' \cdot 50' = 0.020,$$

$$Q = 596 \text{ cfs} \quad V_{\text{ave}} = 8.74 \text{ fps} \quad \frac{V^2}{2g} = 1.125' \quad H = 1.067 + 1.0 = 2.07'$$



check capacity by alternate method

$$Q = (0.79)(68.25 \text{ ft}^2) \sqrt{2g(2.5)} = 684 \text{ cfs}$$

$$\text{Use } Q = 670 \text{ cfs}$$

*Consider available storage in Lower Massachusetts Pond*

Lower Massachusetts Pond (Elev. 154)

$$\begin{array}{r} 8615 \\ 8587 \\ 8545 \\ 8513 \\ \hline 3 \overline{) 1.02} \\ 0.34 @ \left( \frac{600}{5.82} \right) (2000 \frac{1}{11})^2 = 1,385,900 \text{ ft}^3 - (400' \cdot 1250') = 1,385,900 \text{ ft}^3 \end{array}$$

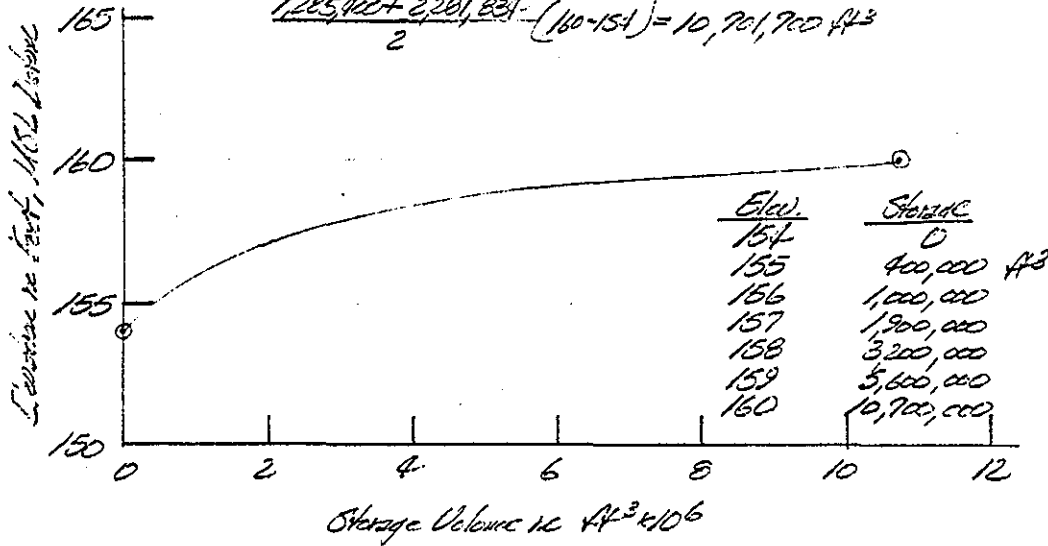
island

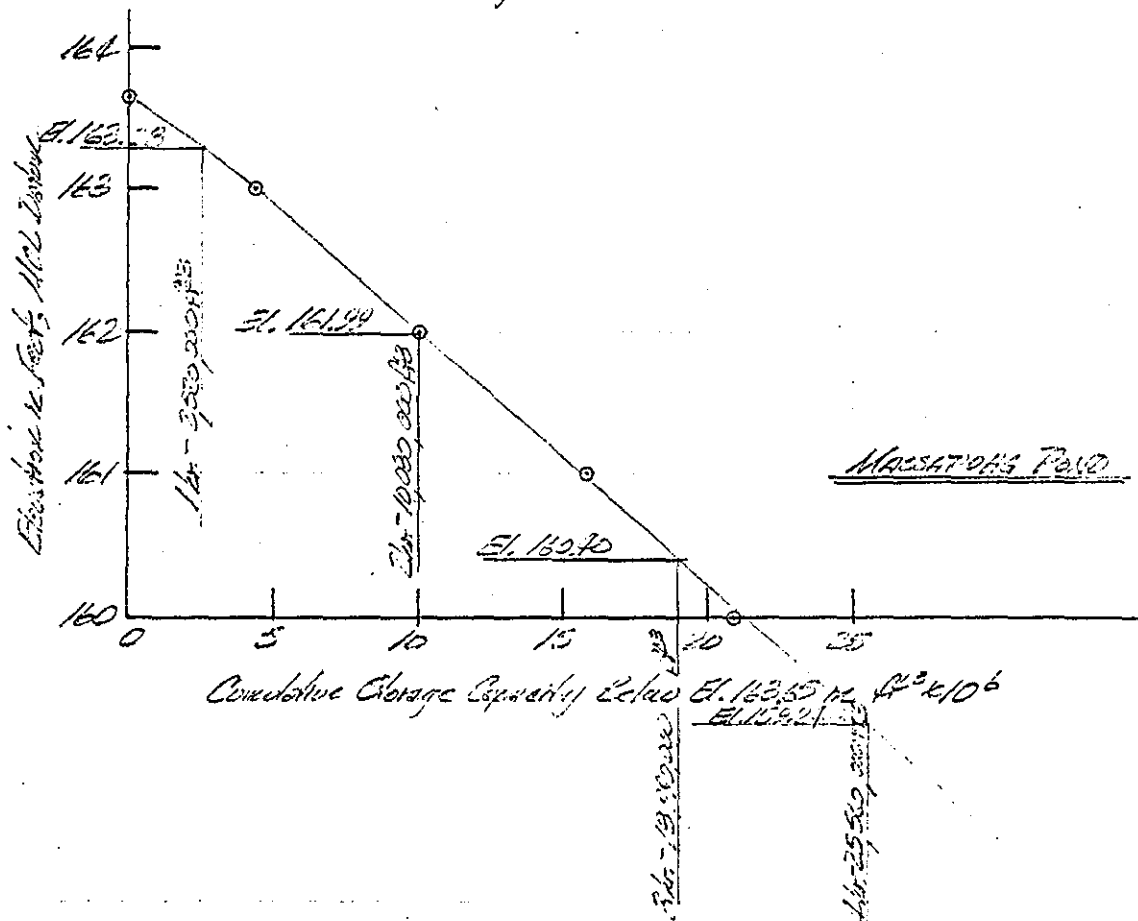
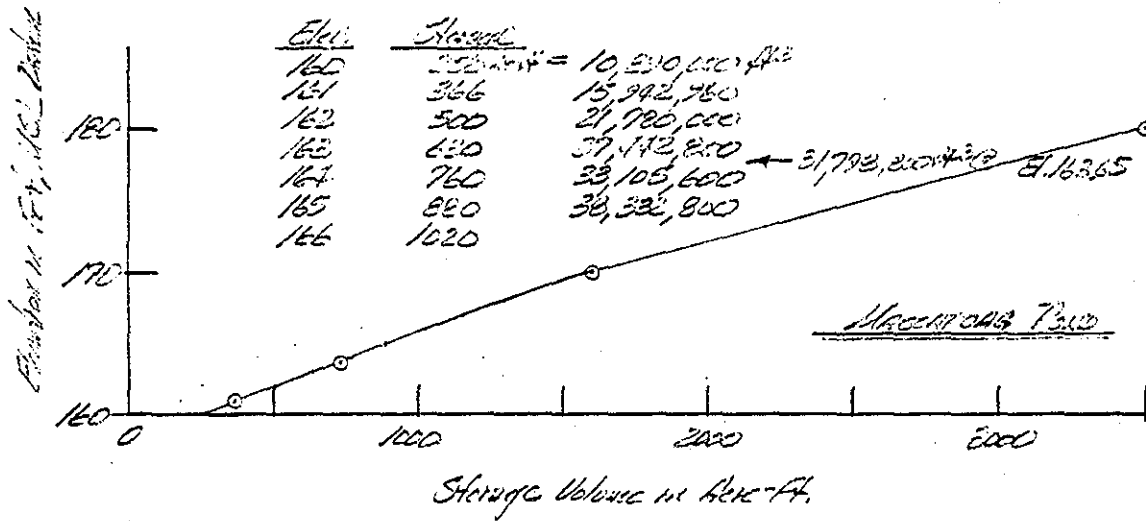
Elev. 160

$$\begin{array}{r} 8727 \\ 8670 \\ 8615 \\ \hline 2 \overline{) 1.12} \\ 0.56 @ \left( \frac{600}{5.82} \right) (2000 \frac{1}{11})^2 = 2,281,834 \text{ ft}^3 \end{array}$$

Total Available Storage between Elev. 154 and Elev. 160

$$\frac{1,385,900 + 2,281,834}{2} - (160 - 154) = 10,701,700 \text{ ft}^3$$

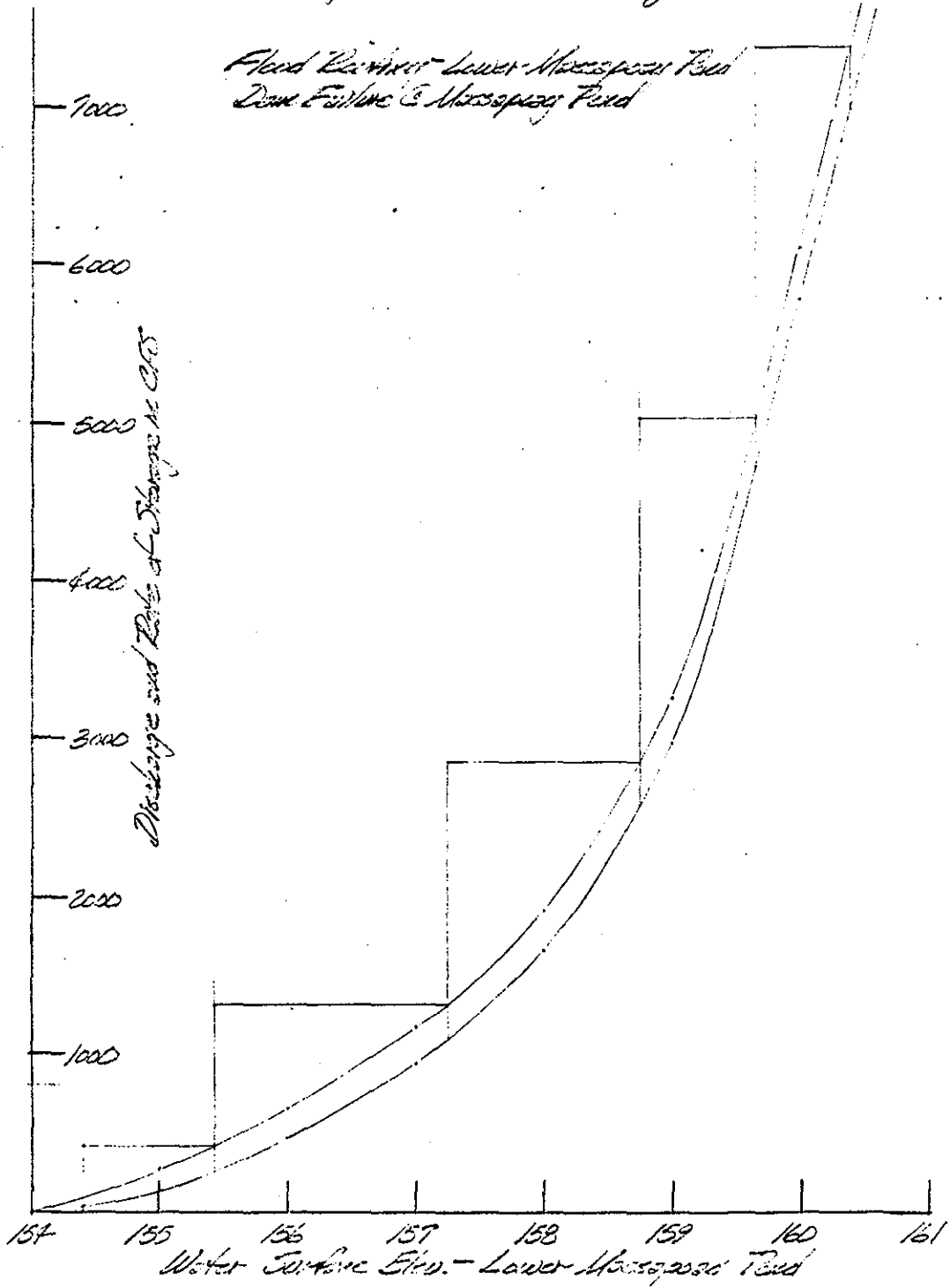


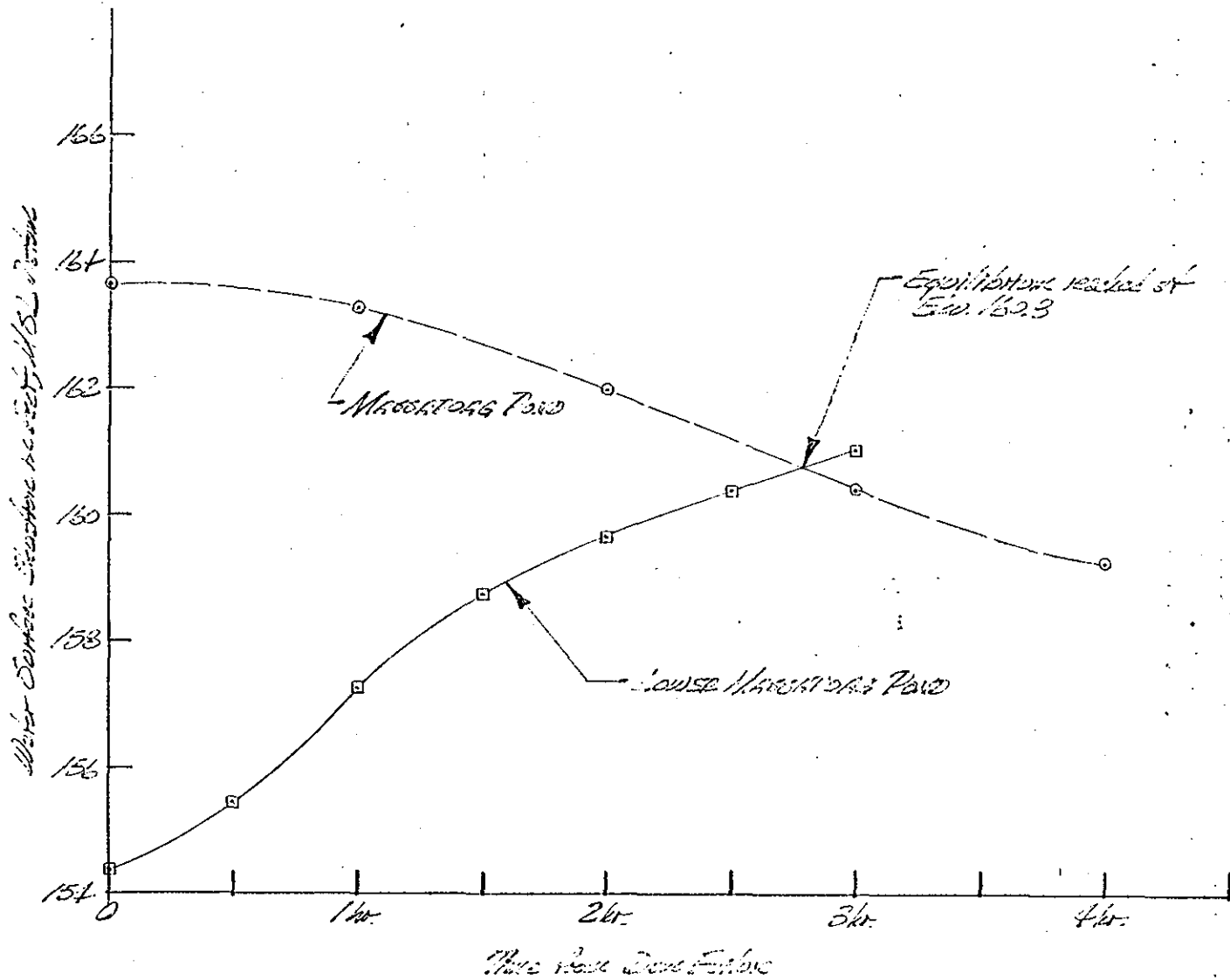


Water Serv. Elev. Lower Masspout Pond (ft)	Water Serv. Elev. Lower Masspout Pond (ft)	Calculated Flow Rate Cfs Cfs Cfs	Flow Rate 5' 16 1/2	$\frac{5}{47}$ (cfs)	$\frac{5}{47} - \frac{Q}{2}$ (cfs)	$\frac{5}{47} + \frac{Q}{2}$ (cfs)
154	1285,900 <sup>15</sup>	15 cfs	0			
155	—	110	400,000	222.2	169.2	577.2
156	—	130	1,000,000	555.6	463.6	615.6
157	—	230	1,900,000	1055.6	990.6	1170.6
158	—	257	3,200,000	1777.3	1649	1905
159	—	280	5,600,000	3111.1	2871	3251
160	2,281,234	315	10,700,000	5914.1	5789	6102
161	—	380				

Flood Routing - Lower Masspout Pond - One Failure & Masspout Pond

Time Hour	Observed Inflow 16 1/2 cfs	Average Inflow 16 1/2 cfs	$\frac{5}{47} - \frac{Q}{2}$ (cfs)	$\frac{5}{47} + \frac{Q}{2}$ (cfs)	Outflow Q (cfs)	Water Serv. Elev. Lower Masspout Pond (ft)
0	0	0			73.08	154.40
1	20 <sup>16</sup>	702.66	70	420	150	155.12
2	140	1050	240	1310	239	157.55
3	1400	1750	1080	2840	275	158.75
4	2100	2450	2490	5040	300	159.65
5	2475	2640	4930	7370	346	160.40
6	2150	3310	7000	9310	381	161.02
7	1225	1990	8540	10750		
8	1500	1650				
9	1170	1340				
10	840	1000				
11	510	675				
12	180	345				







APPENDIX E  
INFORMATION AS CONTAINED IN  
THE NATIONAL INVENTORY OF DAMS